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Henry Ford Hospital

DIVISION OF NEUROLOGY
WILLIAM C. NOSHAY, M.D.
KENNETH H. KAPPHAHN, M.D.
H. F. LABSAN, M.D.
J. A. R. TIBBLES, M.D.

2799 WEST GRAND BOULEVARD
DETROIT, MICHIGAN 48202

DEPARTMENT OF NEUROLOGY AND PSYCHIATRY
LORNE D. PROCTOR, M.D.

DIVISION OF PSYCHIATRY
EUGENE J. ALEXANDER, M.D.
WALTER L. GRAHAM, JR., M.D.
ROBERT R. SCHOPBACH, M.D.
ANDREAS MARCOTTY, M.D.
GERALD G. POPE, M.D.
DONAL L. WHITE, M.D.

SECTION OF PSYCHOLOGY
MARY I. BLAKE, PH.D.
OSCAR SIMPSON, M.A.
T. K. NELDER, M.A.

April 15, 1964

Winnie M. Morgan, M.D.
Report Control Officer
Grants and Research Contracts
Office of Space Science
National Aeronautics and Space Administration
Washington 25, D.C.

Re: Voucher No. 10 for Contract NASr-83

Dear Dr. Morgan:

The following is our progress report for the period January 1, 1964 through March 31, 1964.

Monkey Project

Since commencement of this research project, 2 sixty hour test runs, 119 forty-eight hour test runs, 2 forty-two hour test runs and 2 twenty-four hour test runs have been made, and 28 of these orbits were completed this quarter under standard environmental conditions of medium white light and white noise. Orbit durations were as follows: 3 of six hours, 2 of twenty-four hours, 2 of forty-two hours, 19 of forty-eight hours and 2 of sixty hours. The purpose of the six hour orbits was calibration of the EEG equipment, and no problems were presented. The distribution of the 28 orbits over the five senior Nemestrina monkeys was as follows: NA-3, 4 orbits; NA-4, 8 orbits; NA-5, 10 orbits; NA-6, 4 orbits; and NA-9, 2 orbits.

During this quarter the interpolated cue problem, which was developed late in the last quarter and described in the January quarterly report, was used in orbit. In brief, this was a matching-from-sample task in which the animal's responses produced first the sample to be matched, then an unpredictable number of irrelevant cues similar to the sample, and finally the pair of cues from which he was to select the one like the sample. Initially, for each animal, half of the problems had no irrelevant cues and the other half, randomly determined, just one irrelevant cue. Four of the animals are still at this level of the problem averaging 70 to 85 percent correct (Figures 1, 2, 3, and 4). The fifth monkey (NA-5) averaged over 90 percent correct throughout a 60 hour orbit on the next level of the problem (0, 1, or 2 irrelevant cues), and will be given an additional irrelevant cue when the equipment arrives to program it (Figure 5). This is as complicated as this problem will be made for the monkeys.

All of the monkeys learned the reversal problem this quarter, and the reversals by session were replaced by mid-session reversals for four of the monkeys (Figures 6, 7, 8, and 9), and by reversals every six trials of a 24 problem session for NA-5 (Figure 10).

The matter of problem difficulty has now been settled with two problems of variable difficulty, but it was clear that there was no problem of this type which would be easy enough to permit great accuracy at the beginning of a 48 hour orbit, and yet deteriorate under a regimen of three 8 trial sessions per hour with rest in between. Therefore, the number of sessions per hour was increased to four, and the number of problems in each session tripled. Now the only parts of each hour not devoted to problems were the three minute periods of EEG recording before each of the four sessions. These periods were interrupted for 30 seconds mid-way by a buzzer. The orbits were extended to 60 hours.

To enforce this long and heavy work schedule, especially during the low points of the diurnal cycle, the monkey had to be punished when he failed to respond to the problems. A blast of air to the monkey's face was tried first, but this was inadequate, so in the last eight orbits the animals received 200 msec. of shock on one thigh whenever they did not perform. Correct responses were still reinforced with sugar pellets (Figure 11).

In this situation NA-5 showed a decrement over time in output on the matching-from-sample problem with the irrelevant cues (Figure 5), and a decrement in accuracy on the reversal problem (Figure 10).

During this quarter environmental conditions were kept constant so that we might develop a test program to give a reliable performance decrement in output and accuracy over 48 to 60 hour orbits.

NA-4 showed some decrement over time in both accuracy and output on the matching problem (Figure 4). The only decrement on the reversal occurred in output at the low points of the diurnal cycle (Figure 9). A harder version of the reversal problem will be used in the next orbit of this animal.

NA-3, NA-6, and NA-9 have been orbited very little this quarter and had, at most, one exposure to shock. Their output in orbit has been very low (Figures 1 to 3 and 6 to 8). The reason NA-6 and NA-9 have been orbited so little has been the slow recovery of skin and periosteum in the head plug area from a teflon plug, which was not tolerated, and subsequent surgery to remove it. The teflon was used because it was certain not to affect the EEG. The new plugs are of vitallium as earlier ones. This material is tolerated so well that the bone will grow over it where the fit is exact. NA-3 was seldom selected for orbits because of his consistently poor performance at the training panel. Although his performance is somewhat better in orbit, he will probably be retired next quarter. It is increasingly more apparent as we progress with our primate testing that there is only a portion of a primate colony capable of reliable performance. The other two low output monkeys will be orbited as frequently as possible next quarter in the hope that their output can be brought up to earlier high levels in the same manner as the output of NA-4 was increased this quarter (Figure 11).

Training of the five new Nemestrina monkeys, NA-10, NA-11, NA-12, NA-13, and NA-14, was begun this quarter. All of these monkeys except NA-14 adapted to the chairs and learned to operate the training panel. NA-10 and NA-12 are now being trained to respond consistently to one of two colors (simple discriminations), and NA-11 and NA-13 have mastered this task and are now working at reversal problems with color cues. NA-14 died shortly after his first chairing. Autopsy did not reveal the cause of death, and this matter is being investigated further.

A test was made of the feasibility of surface electrodes to monitor EEG's over a 48 hour period. Electrode paste was replaced twice daily and good recordings were obtained throughout the orbit.

The alerting cues were discontinued this quarter because shock prevented the animals from dozing through entire sets of problems and thus eliminated the usefulness of alerting cues in the one 6 hour block at the low point of the diurnal cycle where it was apparent last quarter (Figure 12).

Chimpanzee Project

The chimpanzees were trained to operate the test panel without restraint early in the quarter, and then adapted to the space chamber and space chair. The latter was modified to reduce the amount of laceration as they struggled. They now give only token resistance to chairing and respond readily to the panel while in the chair.

Both chimpanzees have learned simple color discriminations and are now working at reversal problems. Kenny has adjusted to reversals every 40 trials, but Fletcher still refuses to change his choices and gets upset when the apparatus no longer vends banana pellets. The frequency of the reversals will gradually be increased. It is planned that eventually these animals will be given tick tack toe problems similar to those used at UCLA, and work has begun on equipment for this project.

Fletcher still has severe diarrhea almost continuously and has not gained any weight. Kenny has gained weight, but has a heart murmur which has been diagnosed as mitral stenosis. Work is continuing with him on the assumption that the defect is congenital and will not progress. Two more chimpanzees are slated to arrive next quarter.

Human Project

The two human problems mentioned in the last quarterly report have been worked out in greater detail this quarter, and the wiring for the human orbits is almost complete. Testing should begin in April. The task in which the subject must select a given sequence of patterns out of a larger sequence has been modified so that the sequence to be picked out has five rather than four units. The other problem involves concurrent alternation of the correct member of three different sets of symbols. Each of the three sets is presented before any set appears again, so the subject must alternate his choices on the basis of what he did three trials earlier.

A version of the tick tack toe problem planned for the chimpanzees may also be tried on the human subjects.

EEG and Computer Reports

The EEG was recorded during all of the orbits; however, visual analysis of records was confined to portions of the total EEG on any orbit. There are several reasons for this. For some orbits the program was increased to three trial sessions per hour, thus increasing the length of the EEG record by 50 percent. The results of our computer analysis suggested that the differences in the various frequency bands were quantitative rather than qualitative and, although consistent, were too small to be appreciated by the eye. In addition to this, we have verified that the ink pen representation of the EEG bears little resemblance to the brain activity detected by the amplifiers. We have confirmed this by comparing the cathode ray oscilloscope pattern with the written record. Further evidence is furnished by the reconversion of our digitized EEG record to an analogue record using a Cal-Comp plotter as the output of the computer. The reconstituted record matches the oscilloscope trace, but only slightly resembles the ink written record. All of the written records are stored, however, for future reference, should the need arise.

We have four records that have a complete computer analysis for all band widths from 1/2 to 50 cps. Since none of these animals showed a decrement in their behavior during the simulated orbit, they will serve for a base line study. We are trying various ways of graphically representing the results and some samples are included in this report. With our zero crossings analysis we can account for 85 to 90 percent of the activity, and the part that is lost must lie without the range of our analysis; that is, below 1/2 cps and above 50 cps.

Figure 15 shows the amount of 1/3 to 3 cps delta (δ) activity during each trial for the 48 hour orbit. This pattern differs from that in figures 22a and 22b which depicts the delta activity of another animal during orbit. In the first case, there were 2 trial sessions per hour and in the latter, 3 sessions per hour. At present the only explanation for the difference in slow wave activity in these two orbits is in consideration of the two known conditions that produce it; namely, sleep and movement. A predominance of delta activity in the performance period would suggest movement as the source, whereas predominance during the preperformance period would suggest sleep as the source.

Figures 16 and 17 show the activity in the other band widths; theta (θ) 4 to 7 cps., alpha (α) 8 to 13 cps., beta 1 (β_1) 14 to 25 cps., beta 2 (β_2) 26 to 35 cps., and beta 3 (β_3) 36 to 50 cps.

Figure 18 shows the amount of the analogue record that is analyzed by our computer program. The range varies from 80 to 95 percent.

Figures 19, 20, and 21 compare the frequency bands of the two hemispheres. There is remarkable symmetry of the increase and decrease of activity in any band from trial to trial during the entire orbit.

Figures 23a and 23b depict the theta activity (4 to 7 cps) during the 3 trial per hour orbit. When these graphs are related to the performance graphs (see figures 13 and 14), there is a definite increase in the amount of theta activity in the high response output periods. However, this amount did not show a definite decrement in the performance accuracy. We are analyzing the records of some orbits in which there was a definite decrement in performance ability over the entire period, and they will be reported in our next communication.

<u>Biotelemetry Report</u>

A telemetry link for the transmission of two signals employing two separate transmitters and two separate receivers is practical if the system is arranged so as to prevent spurious interaction between the two transmitters, as well as between the receivers; this was shown in our progress report of November 10, 1963. If four or more signals have to be transmitted a procedure employing multiplexing should be used for reasons of economy as well as to prevent spurious interactions as referred to above, the chances of which would increase with the number of transmitters and receivers. In the following we report the progress made with a 4 channel system as shown in figure 24.

Pre-amplifiers: The design of amplifiers for the recording of EEG has to take into consideration the noise performance of transistors used in the first two stages of amplification. Fischler and Frei (1), report a noise voltage referred to input of 3 micro-volt peak to peak (p.t.p.) for their amplifiers with a 22 Kilo-ohm source resistance. Using a Tektronix Type 122 low-level amplifier and a Tektronix 502 Oscilloscope, we found the noise voltage referred to input of our 4 Sem-Jacobson (S.J.) pre-amplifiers with 22 kilo-ohm source resistance during an observation period one second long, also to be 3 micro-volt p.t.p. A second design objective is reduction in size. The S.J. units measure 3-1/2 x 7/8 x 3/4 inches, and we are working toward a reduction in size by at least a factor 10. Most of our efforts during the next two or three months will be directed toward the development of preamplifiers using small package transistors (such as JEDEC outlines TO 50, u4, u5, u11 through u23, X16 and X17) having a noise performance better than or equal to the above mentioned amplifiers.

Sub-carrier Oscillators: The band width required for the transmission of one EEG signal is approximately 50 c/s. We, therefore, selected the IRIG bands, no's 8, 9, 10 and 11 with bandwidth of 45, 59, 81 and 110 c/s respectively (band 8 being 5 c/s short of the required width). The center frequencies of these bands are 3000, 3900, 5400 and 7350 c/s respectively, the nominal values of frequency deviation being $\pm$ 7.5 percent of the carrier frequency.

We constructed several subcarrier oscillators using the circuit described by N.J. Lupu (2) which is particularly suited to our needs. The following observations with this circuit, which is shown in our figure 25, are reported:

The curves of figure 26 were obtained with a breadboard version of this circuit. The frequency (f) versus control current (i) curve with a supply voltage (V_s) of 18 volt is slightly concave when viewed from the line f = 800 c/s, whereas, for a supply voltage of 12 volt the curve is slightly convex. The frequency difference between these two curves is plotted on an expanded scale. We conclude that there is a value for the supply voltage between 12 and 18 volts at which optimum linearity is obtained.

The choice of miniature coupling capacitors for C_1, C_2, C_3 turned out to be critical. With tantalum capacitors (T.I. SCM-2) no oscillation could be obtained at all. With Glenite ceramic capacitors (CT-10-102k), oscillation was obtained over a frequency range half as wide as that obtained with the breadboard circuit. Best results were obtained with 1500 Pico-farad Centra-Lab (CRL) ceramic disk capacitors. The circuit with the CRL capacitors could accommodate all four IRIG bands mentioned above by properly biasing the control current. This is illustrated in figure 27 where IRIG bands and corresponding ranges of control current are indicated. A 2N1613 NPN Silicon transistor with very low I_{CBO} is used in the common base configuration with a 10 kilo-ohm resistor in the emitterloop to provide the control current. The pre-amplifier gain required with this arrangement is approximately 1000.

Construction: The components were placed between two cambric boards with the leads protruding through holes in the boards (as in cord-wood modules) providing a near optimum layout and density. This assembly was then placed in a niche leaving only the top-side open. RTV Silastic (a Dow Corning Room Temperature Vulcanizing silicone rubber) was then poured into the niche so as to embed the components. After setting, the cambric boards were removed and the appropriate leads soldered together. The resulting subcarrier oscillator size was 1/2 x 1/2 x 1-5/8 inches. We feel that the size of this unit may be reduced by a factor 4 or more by further experimenting with components of smaller package but similar characteristics. The pre-amplifier development is considered more urgent however. Figure 27 shows the frequency versus control current for the embedded unit. Curves before and after embedding differ only for frequencies above 9000 c/s.

<u>Transmitter</u>: We plan to use a transmitter similar to the one mentioned in our progress report of April 17, 1963.

<u>Receiver</u>: The Sherwood Model 3000 III F-M receiver will be used.

<u>Telemetry band pass filters</u>: UTC United Transformer Corporation (UTC) telemetry band-pass filters TMN 3.0, TMN 3.9, TMN 5.4, and TMN 7.35 are presently on order.

<u>Demodulators</u>: The demodulator circuit described by Harry Ludwig and Carlos Schulz was assembled on bread-board and then tested. Excellent results were obtained with this circuit and it was consequently adopted for our system. In order to accommodate each of the four IRIG bands (see figure 27), the value of only one [redacted] capacitor has to be adjusted properly. The output filter was modified as our bandwidth requirements are 0.5 to 50 c/s whereas Ludwig's design objective was D.C. to 3000 c/s. Our requirements were met with only one UTC MO-50 inductor in the output filter as compared to the two UTC MQA-14 inductors employed by Ludwig. A second demodulator was assembled on a plugboard measuring 4.5 by 6.5 inches (Vector Electronic Company, Cat No 838A P.C. Plugboard) and tested. Components for the construction of a total of four demodulator circuits have been acquired.

<u>Printed Circuit Boards</u>: It is becoming apparent that in order to provide uniformity in construction, ease of testing, ease of servicing and to improve reliability, printed circuit boards are required. With the book "Printed and Integrated Circuitry" by T.D. Schlabach and D.K. Rider,

McGraw-Hill Book Company as a guide and using a Master Photo Layout Kit (Kepro Type L-PL-200) and an Etched Circuit Lab Kit (Kepro Type L-505A-G) to gain some practical experience, we are presently investigating the feasibility of setting up a printed circuit board manufacturing capability using photochemical techniques for the production of very small circuit boards. The first results are very promising.

Hoping you will find this progress report adequate.

Yours sincerely,

Lorne D. Proctor, M.D.,
Chairman - Department of
Neurology and Psychiatry

LDP/B
Enclosures

1. H. Fischler and E.H. Frei, "Subminiature Apparatus for Radio-Telemetering of EEG Data". IEEE Transactions of Bio-Medical Electronics Volume 10, Number 1, pp 29-36, January 1963.

2. N.Z. Lupu, "A Simple FM Subcarrier Oscillator Suitable for Physiological Telemetry". Proceeding of the IEEE Volume 51, Number 11, pp 1621 & 1622, November 1963.

3. Harry Ludwig & Carlos Schulz, "Analog Digital Converter with Unijunction Transistors"; Proceedings of the 1963 16th Annual Conference on Engineering in Medicine and Biology, Baltimore, Maryland, November 1963, pp 142 and 143.

INTERPOLATED CUE PROBLEMS

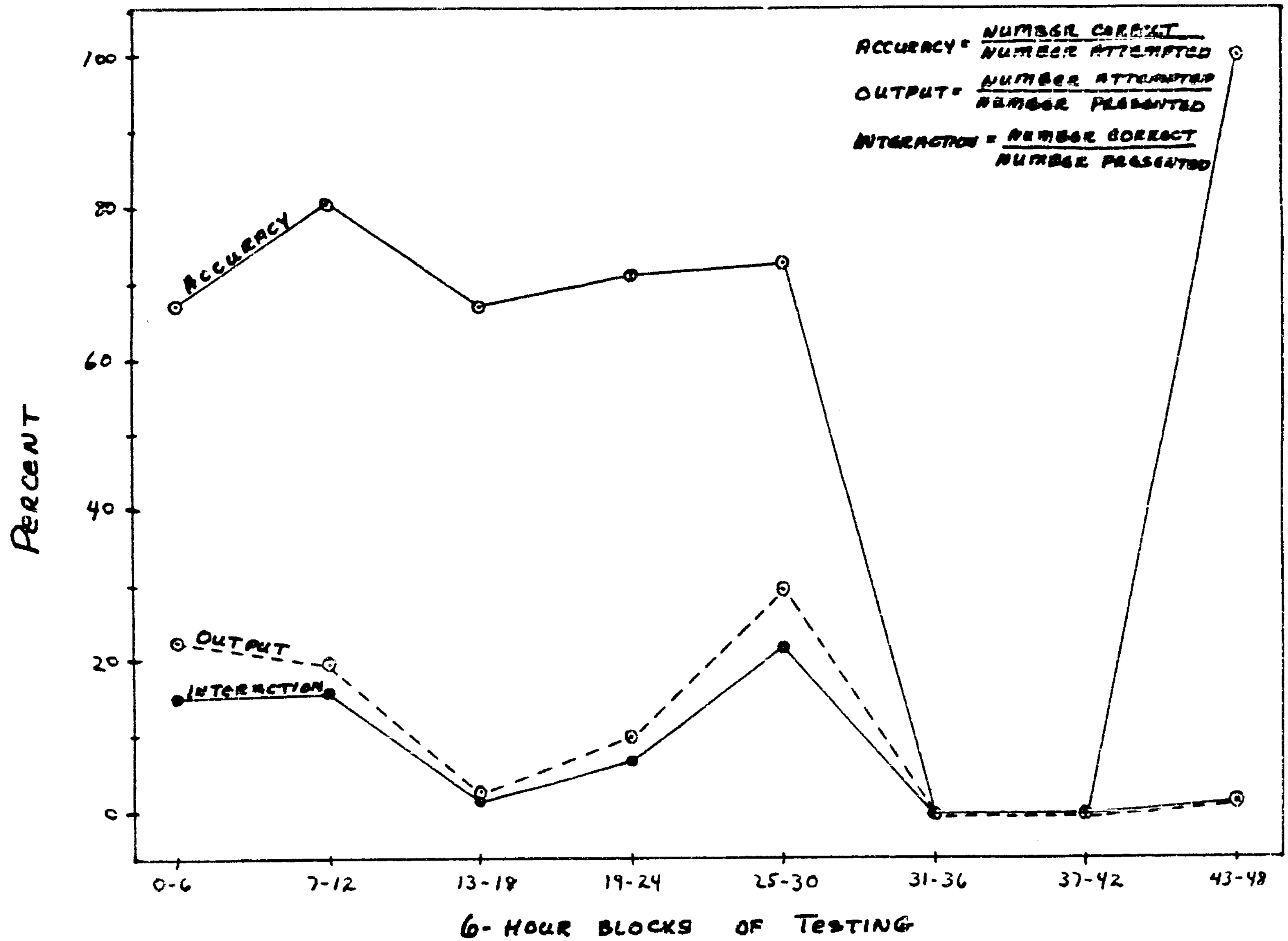

FIGURE 1. PERFORMANCE OF AA-6 ON INTERPOLATED CUE PROBLEMS OF ORBIT 127 IN WHICH SUGAR PELLETS REWARDED CORRECT CHOICES AND SHOCK FOLLOWED TRIALS IN WHICH NO CHOICE WAS MADE. HALF THE PROBLEMS HAVE NO INTERPOLATED CUE, HALF HAVE ONE.

MARCH 31 1964

INTERPOLATED CUE PROBLEMS

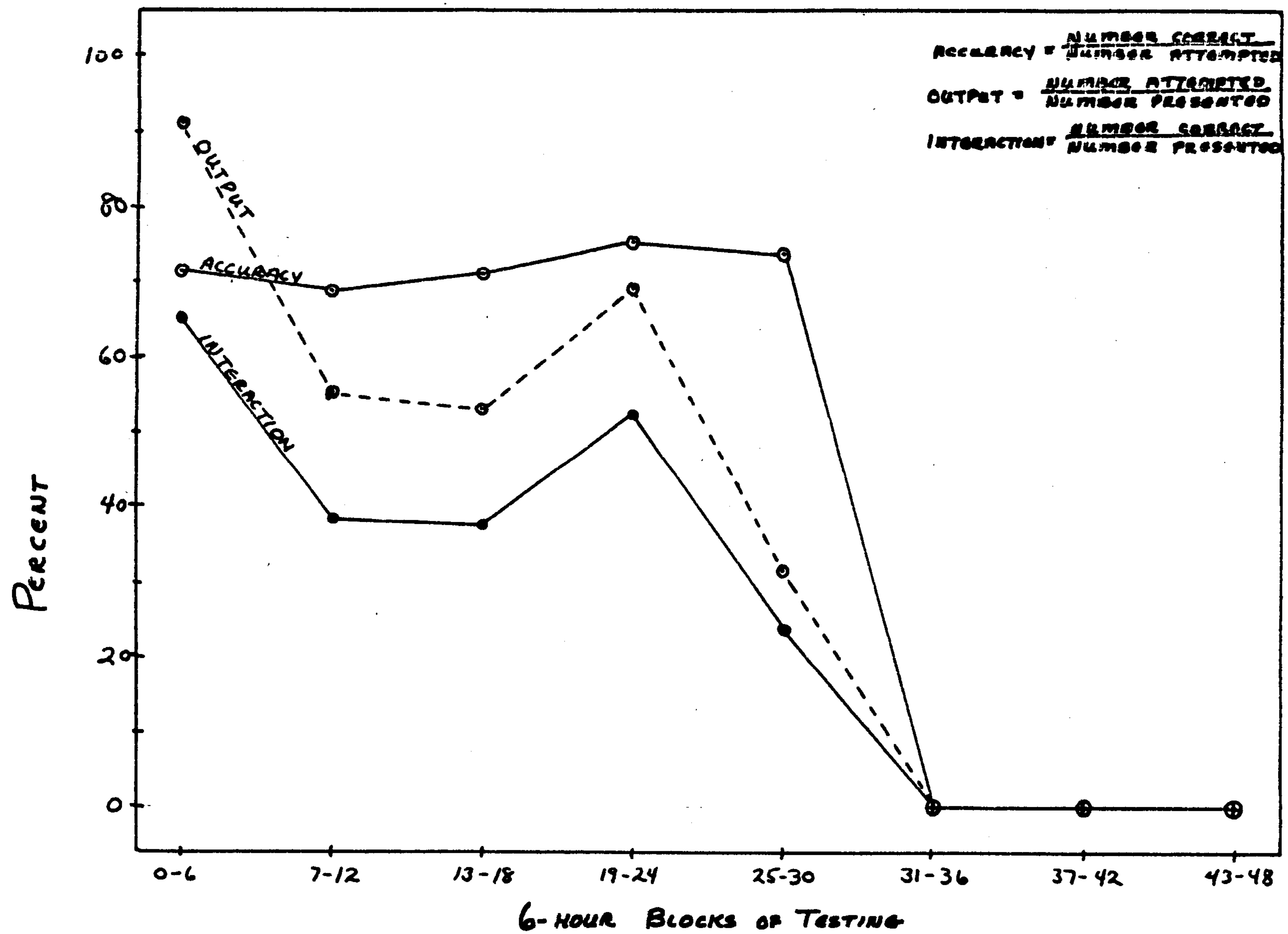

FIGURE 2. PERFORMANCE OF NA-3 ON INTERPOLATED CUE PROBLEMS OF ORBIT 124 IN WHICH SUGAR PELLETS REWARDED CORRECT CHOICES AND SHOCK FOLLOWED TRIALS IN WHICH NO CHOICE WAS MADE. HALF THE PROBLEMS HAVE NO INTERPOLATED CUE AND HALF HAVE ONE.

MARCH 31 1964

Interpolated Cue Problems

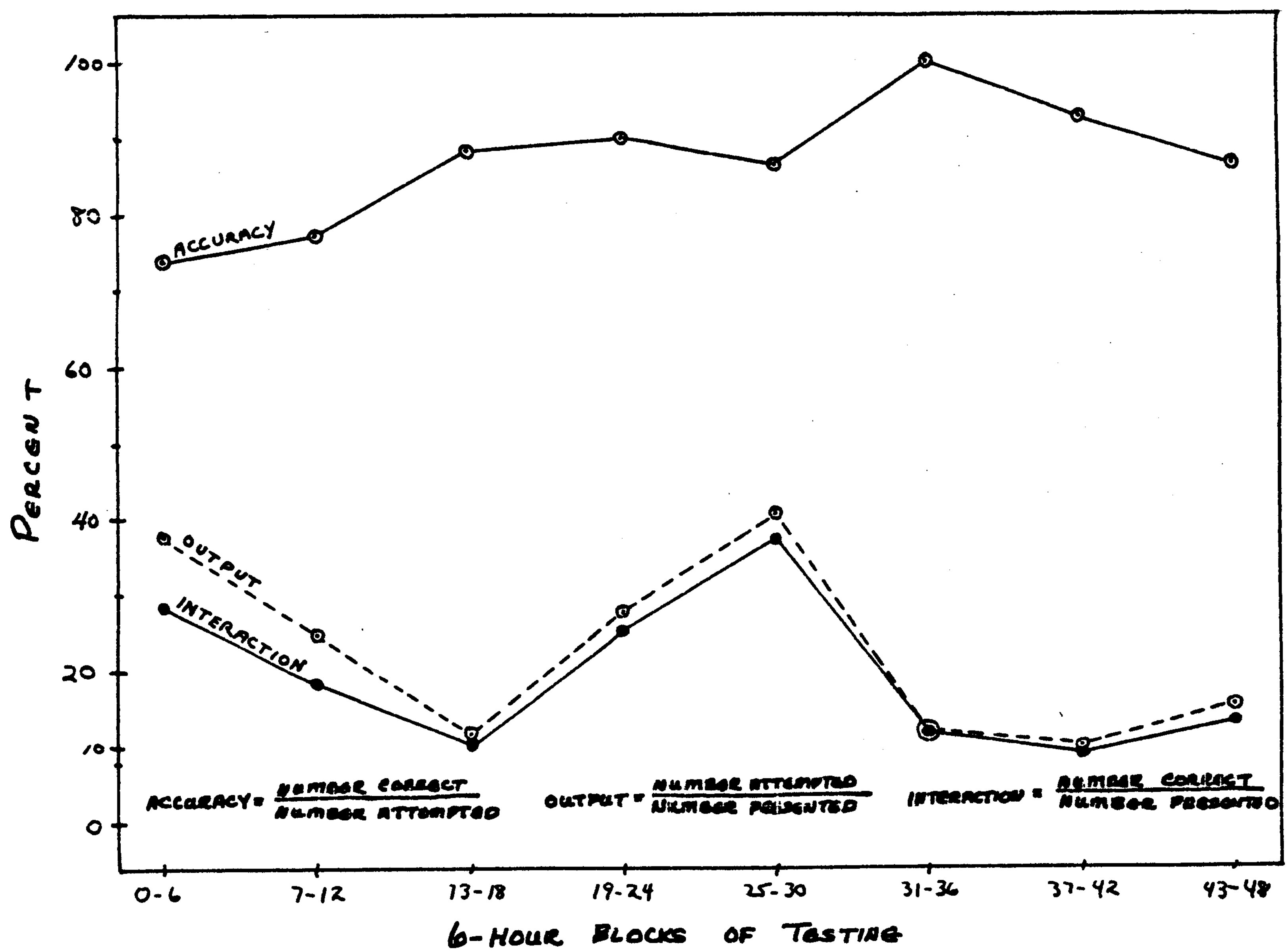

Figure 3. Performance of NA-9 on Interpolated Cue Problems of Orbit III. This animal has not yet been punished for failures to respond to the problems. Half the problems have no interpolated cue and half have one.

March 31 1964

Interpolated Cue Problems

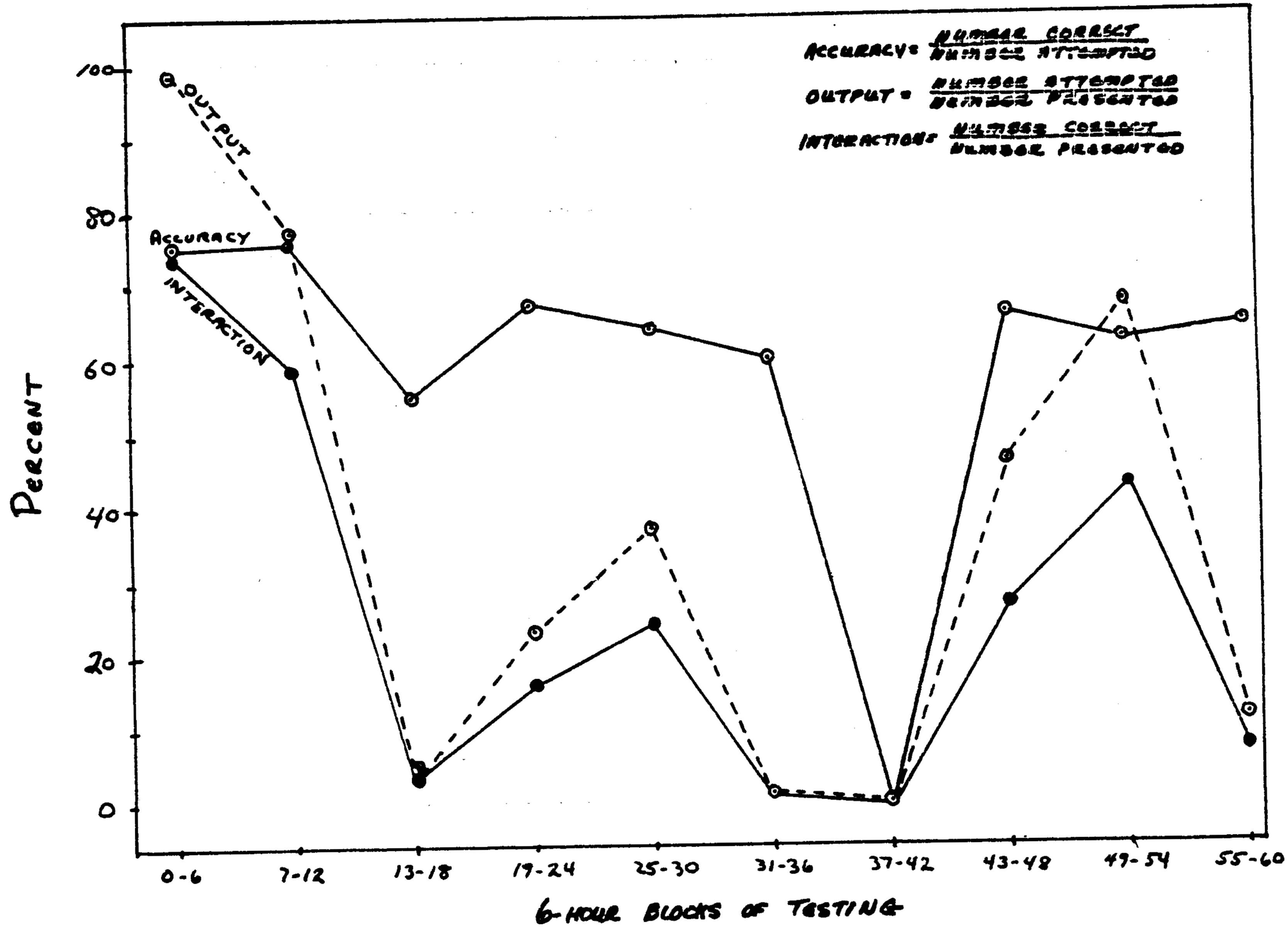

Figure 4. Performance of NA-4 on interpolated cue problems of orbit 128 in which sugar pellets rewarded correct choices and shock followed trials in which no choice was made. 60-hour orbit. Half the problems have no interpolated cue and half have one.

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Interpolated Cue Problems

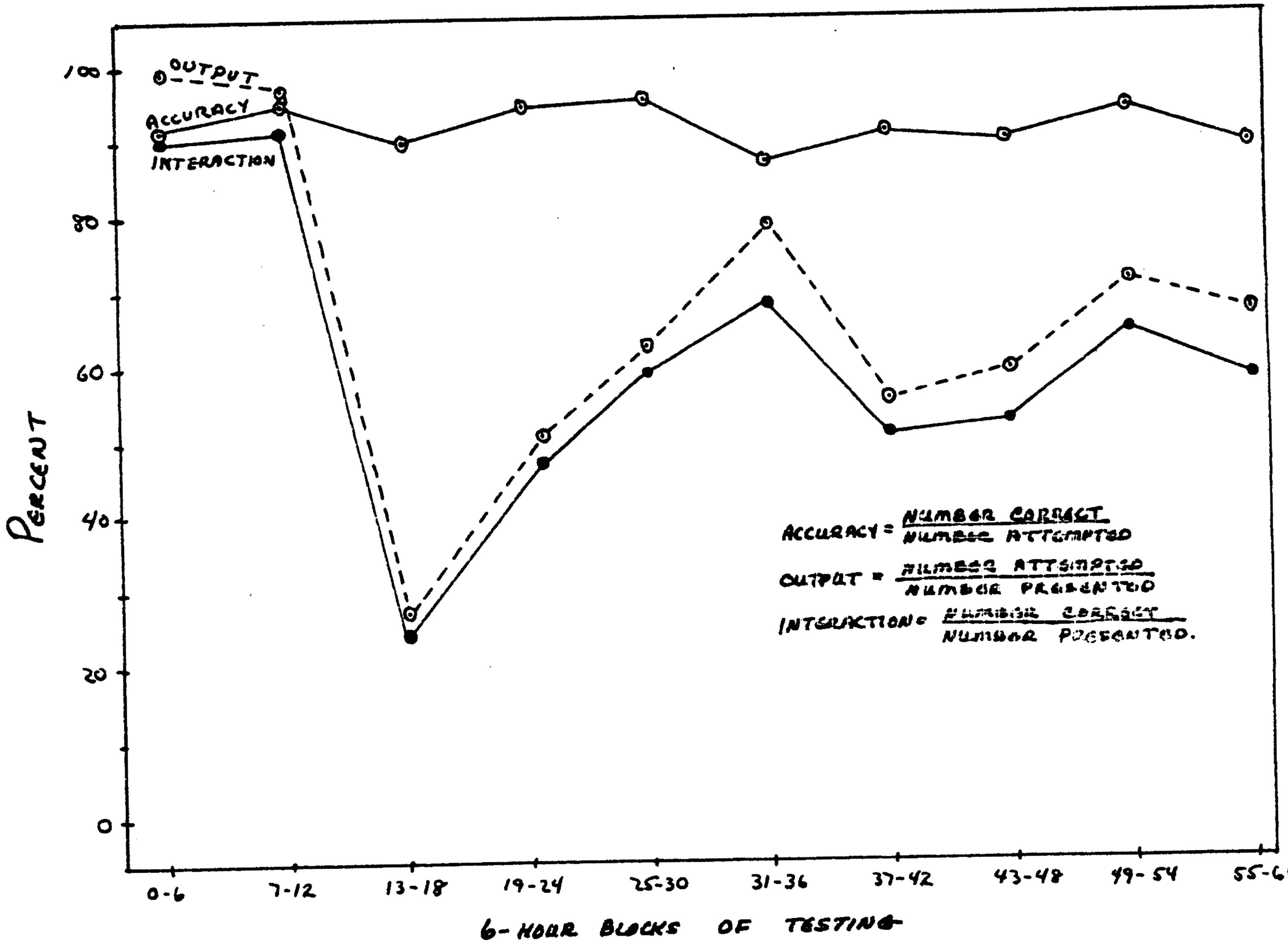


Figure 5. Performance of NA-5 on interpolated cue problems of orbit 126 in which sugar pellets rewarded correct choices and shock followed trials in which no choice was made. 60-hour orbit. One-third of the problems have no interpolated cue, one-third have one, and one-third have two.

March 31, 1964

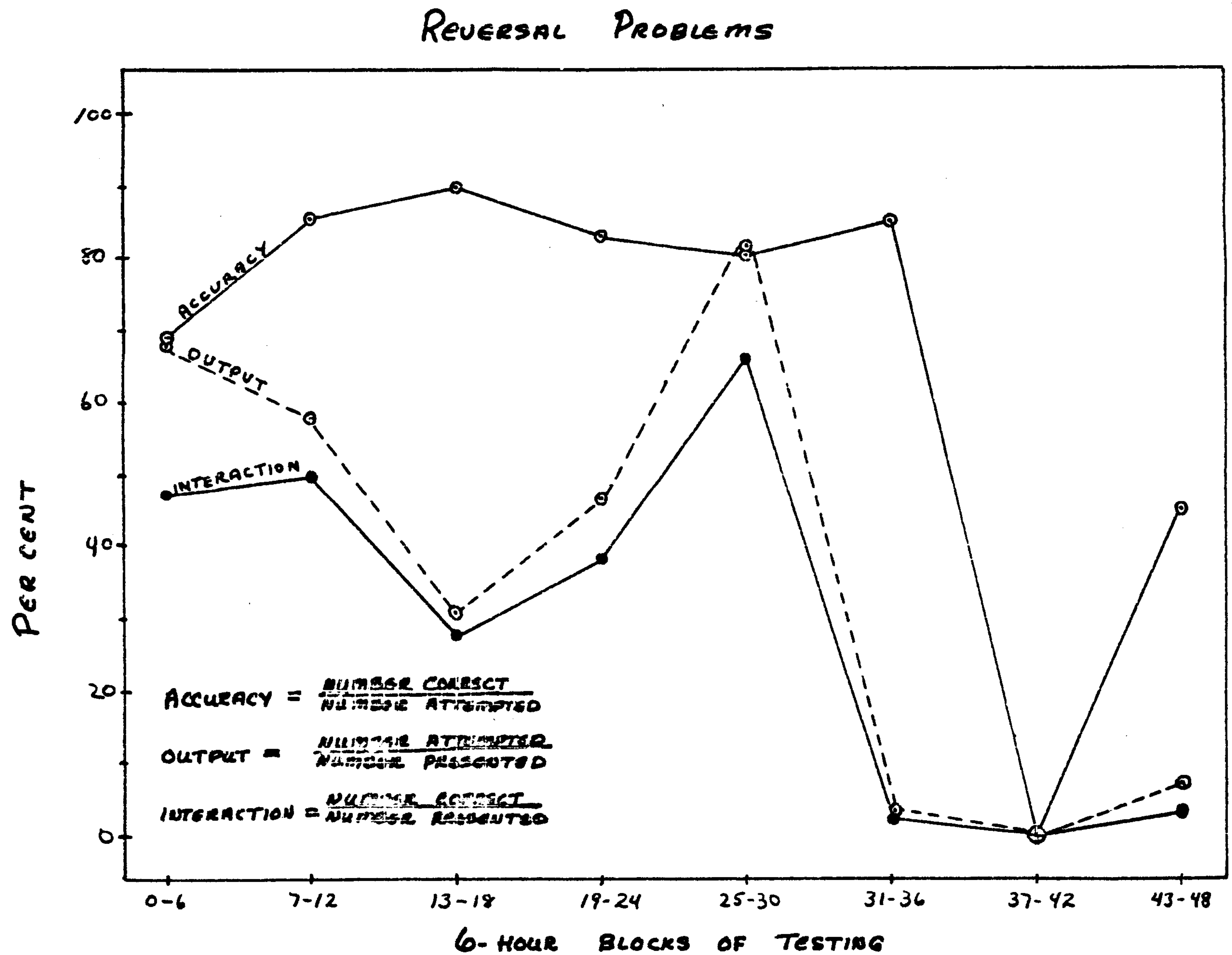


FIGURE 6. PERFORMANCE OF HA-6 ON REVERSAL PROBLEMS OF ORBIT 127 IN WHICH SUGAR PELLETS REWARDED CORRECT CHOICES AND SHOCK FOLLOWED TRIALS IN WHICH NO CHOICE WAS MADE. REVERSAL MID-WAY IN EACH 24-TRIAL SESSION.

MARCH 31 1964

Reversal Problems.

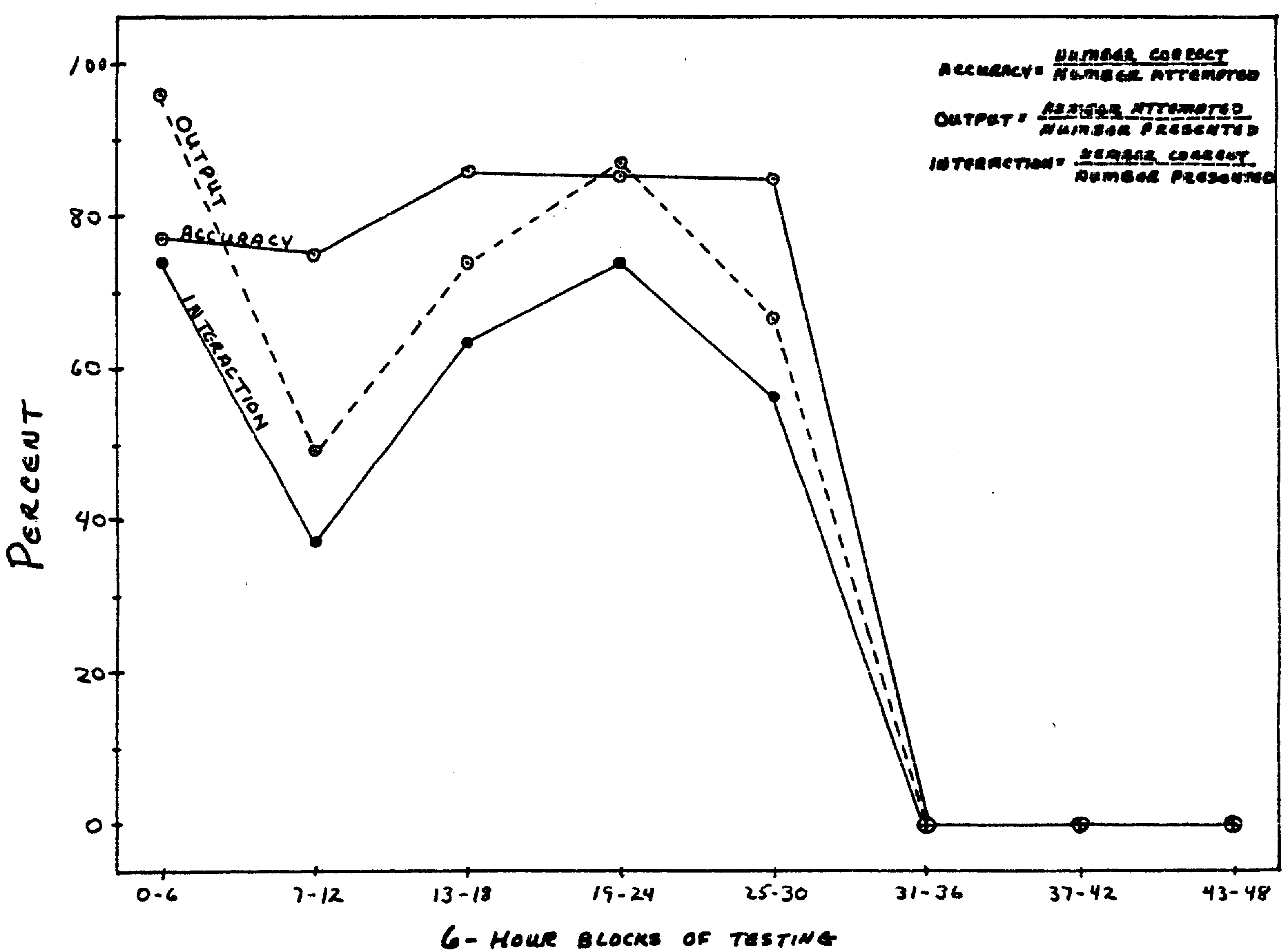


Figure 7. Performance of NA-3 on Reversal Problems of Orbit 124 in which sugar pellets rewarded correct choices and shock followed trials in which no choice was made. Reversal mid-way in each 24-trial session.

March 31 1964

REVERSAL PROBLEMS

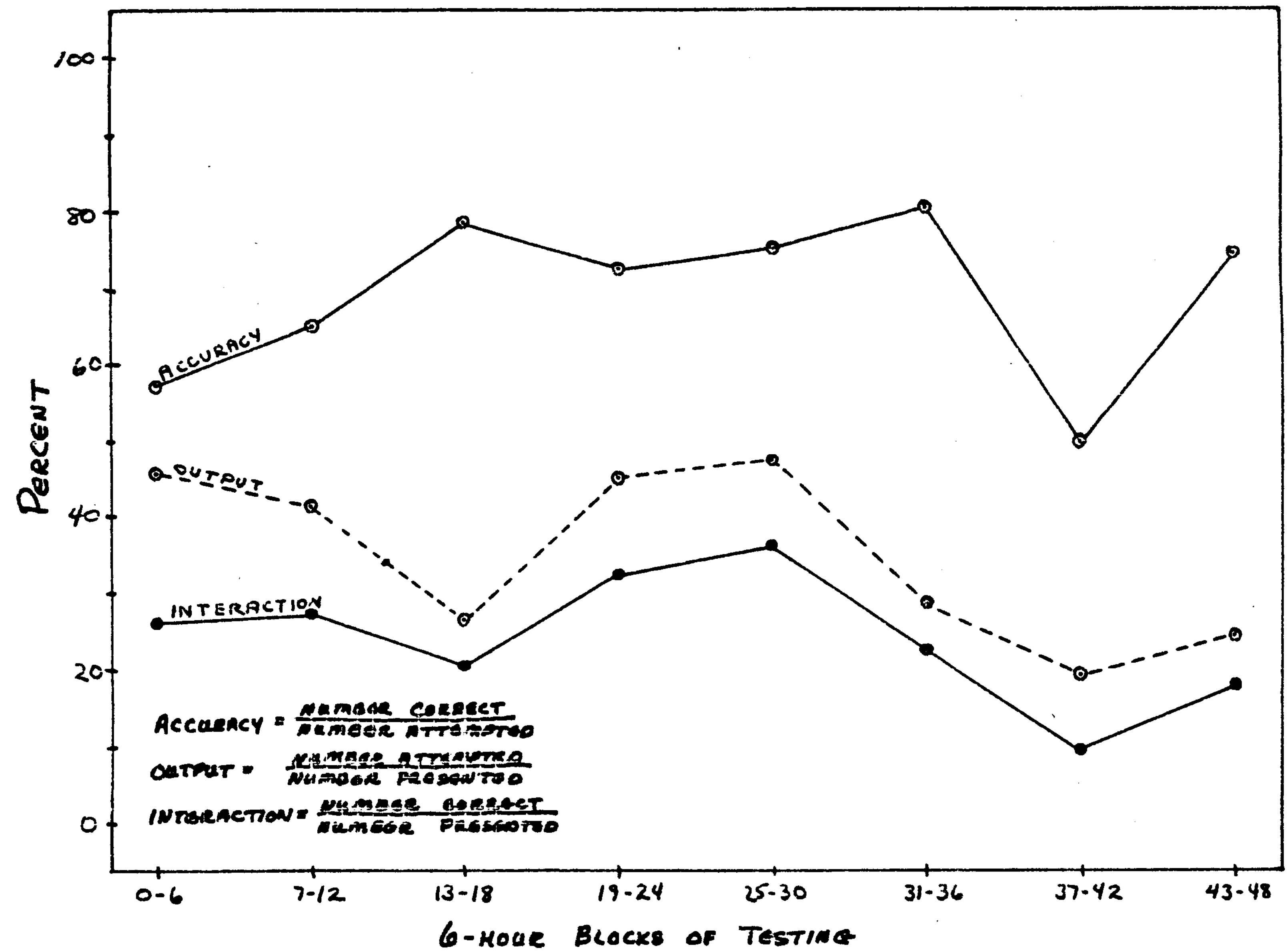


FIGURE 8. PERFORMANCE OF NA-9 ON ORBIT III, REVERSAL PROBLEMS. THIS ANIMAL HAS NOT YET BEEN PUNISHED FOR FAILURES TO RESPOND TO THE PROBLEMS. REVERSAL MID-WAY IN EACH 24-TRIAL SESSION.

MARCH 31 1964

Reversal Problems

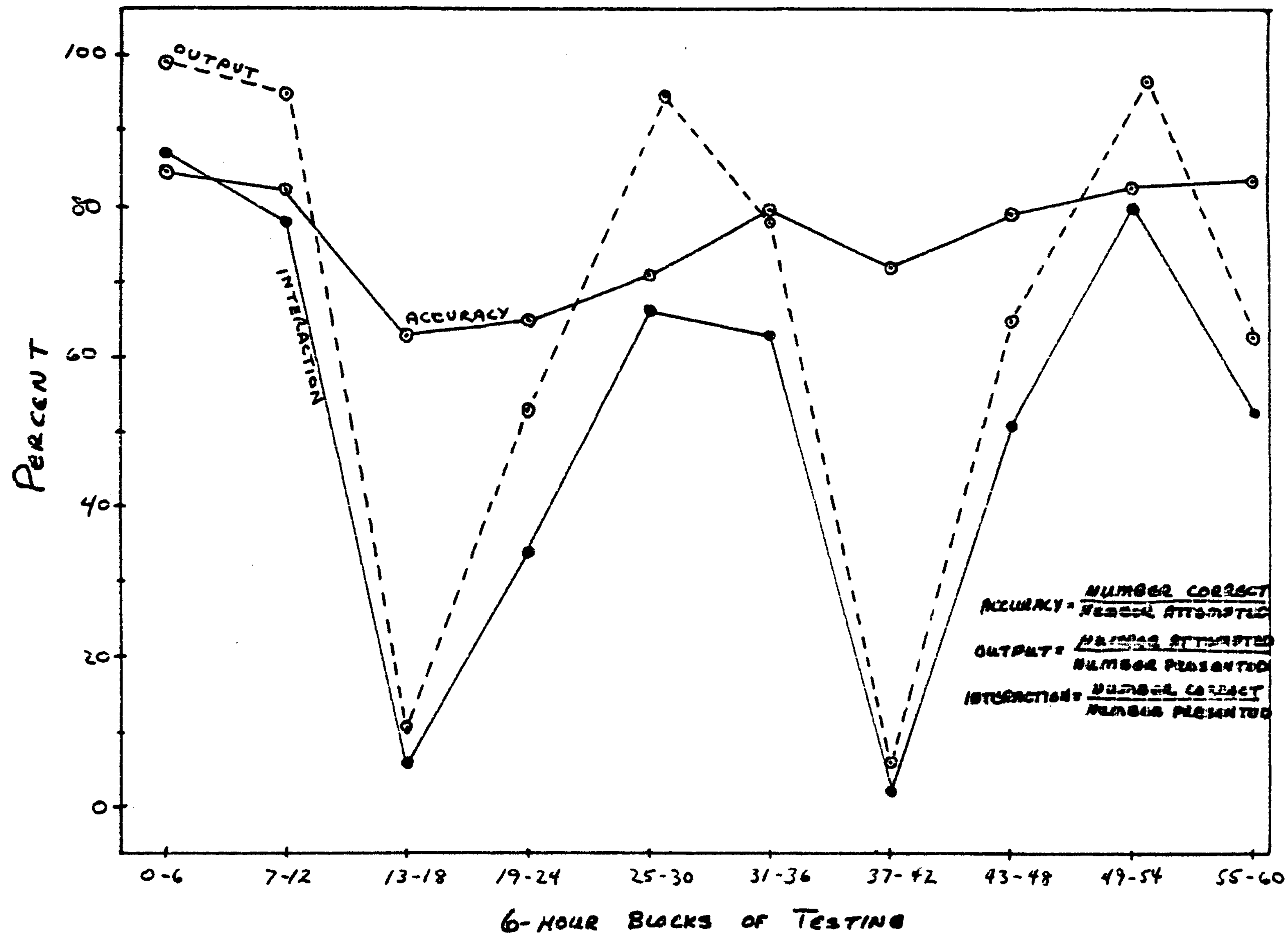


Figure 9. Performance of NA-4 on reversal problems of orbit 128 in which sugar pellets rewarded correct choices and shock followed trials in which no choice was made. 60-hour orbit. Reversal mid-way in each 24-trial session.

March 31, 1964

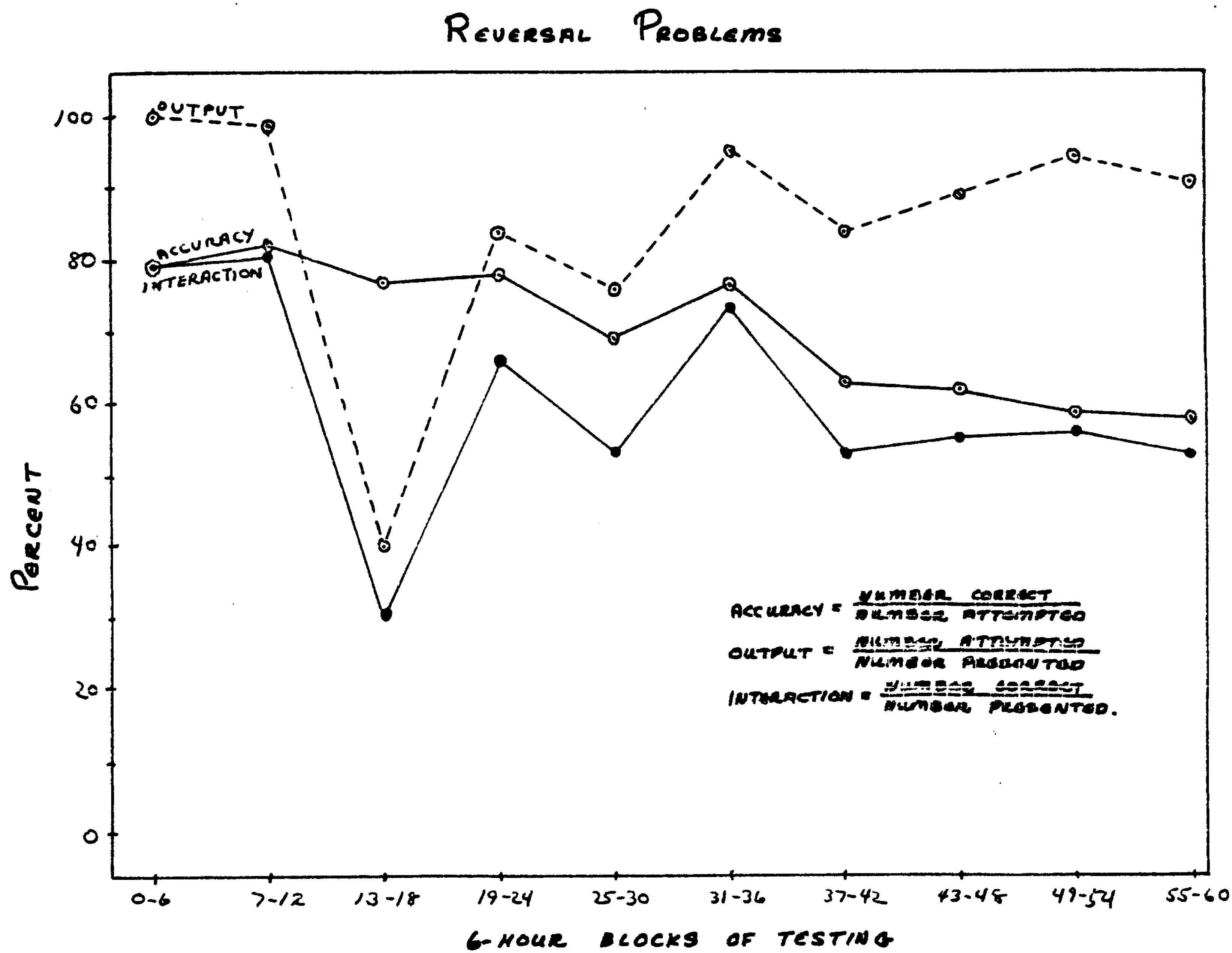


FIGURE 10. PERFORMANCE OF NA-5 ON REVERSAL PROBLEMS OF ORBIT 126 IN WHICH SUGAR PELLETS REWARDED CORRECT CHOICES AND SHOCK FOLLOWED TRIALS IN WHICH NO CHOICE WAS MADE. 60-HOUR ORBIT. REVERSAL EVERY SIX TRIALS IN THE 24-TRIAL SESSIONS.

MARCH 31, 1964

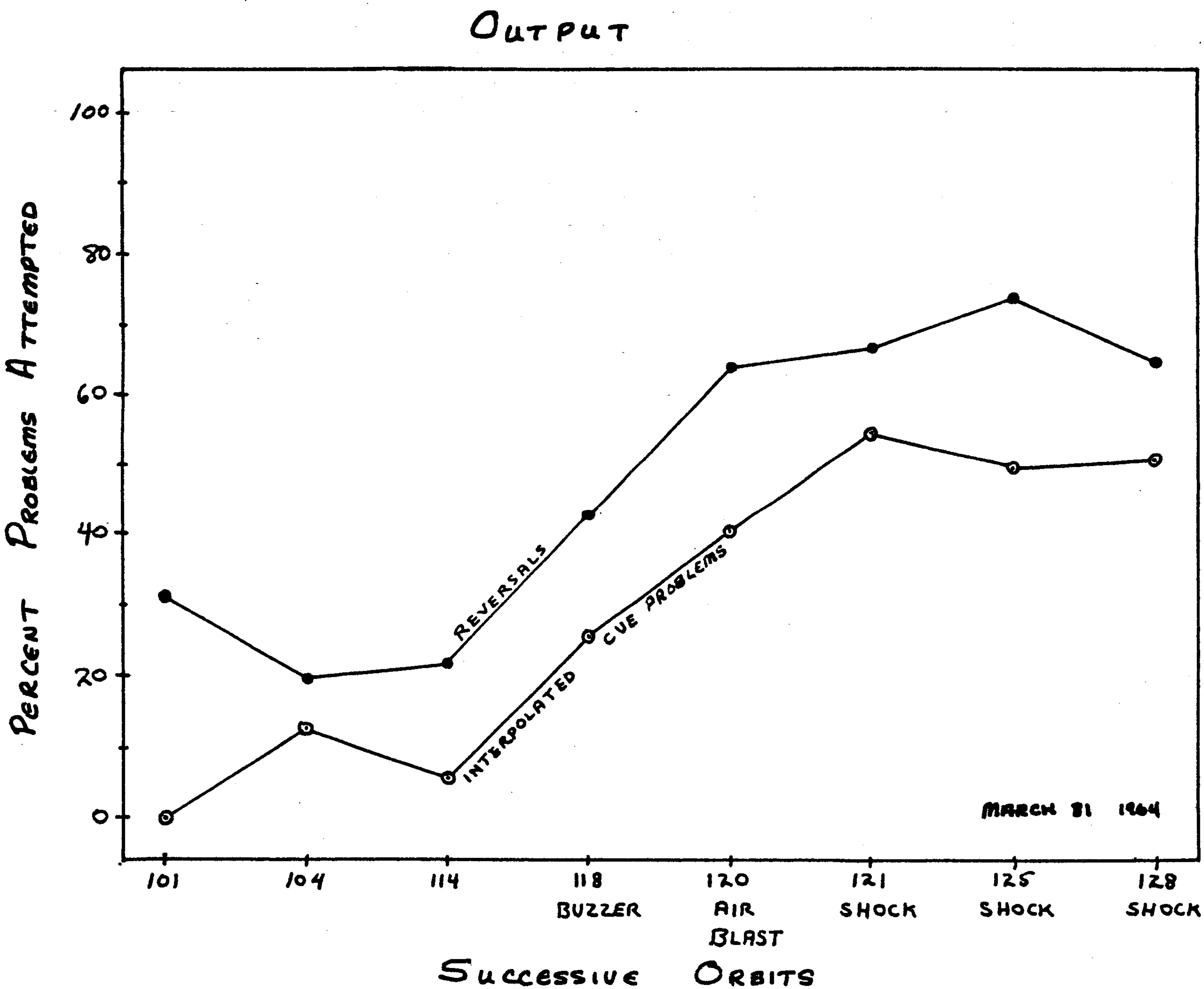


FIGURE 11. RESPONSE OUTPUT OF NA-4 ON REVERSAL AND INTERPOLATED CUE PROBLEMS DURING THE FIRST 24 HOURS OF THE ORBITS HE COMPLETED JANUARY- MARCH, 1964. (INTER-SESSION REST PERIODS WERE INTERRUPTED BY A BUZZER BEGINNING WITH ORBIT 118. FAILURES TO RESPOND WERE PUNISHED BY AN AIR BLAST TO THE FACE IN ORBIT 120 AND SUBSEQUENTLY BY SHOCK.

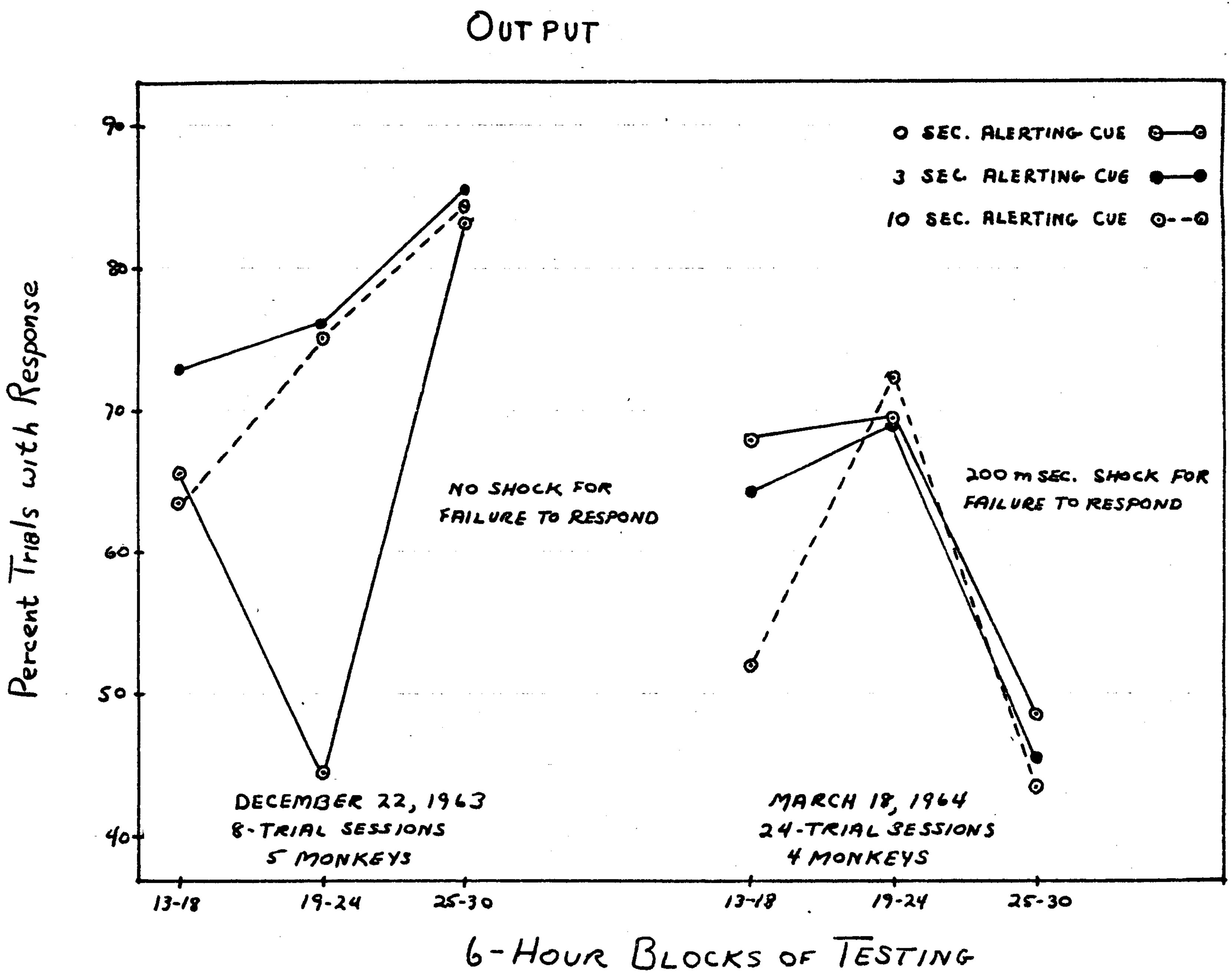
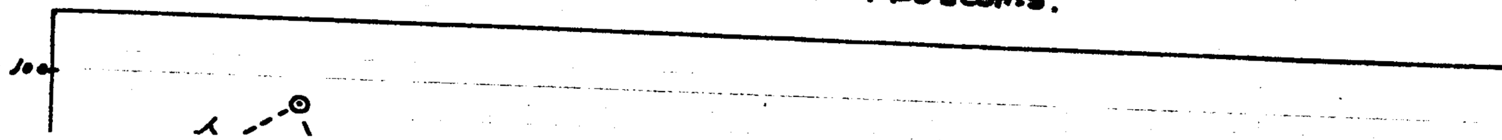


FIGURE 12. RESPONSE OUTPUT OF MONKEYS DURING THE LOW-POINT OF THEIR DIURNAL CYCLE IN PROBLEM SESSIONS PRECEDED BY 0, 3, OR 10 SECOND ALERTING CUES.

MARCH 31, 1964

REVERSAL PROBLEMS.



INTERPOLATED CUE PROBLEMS

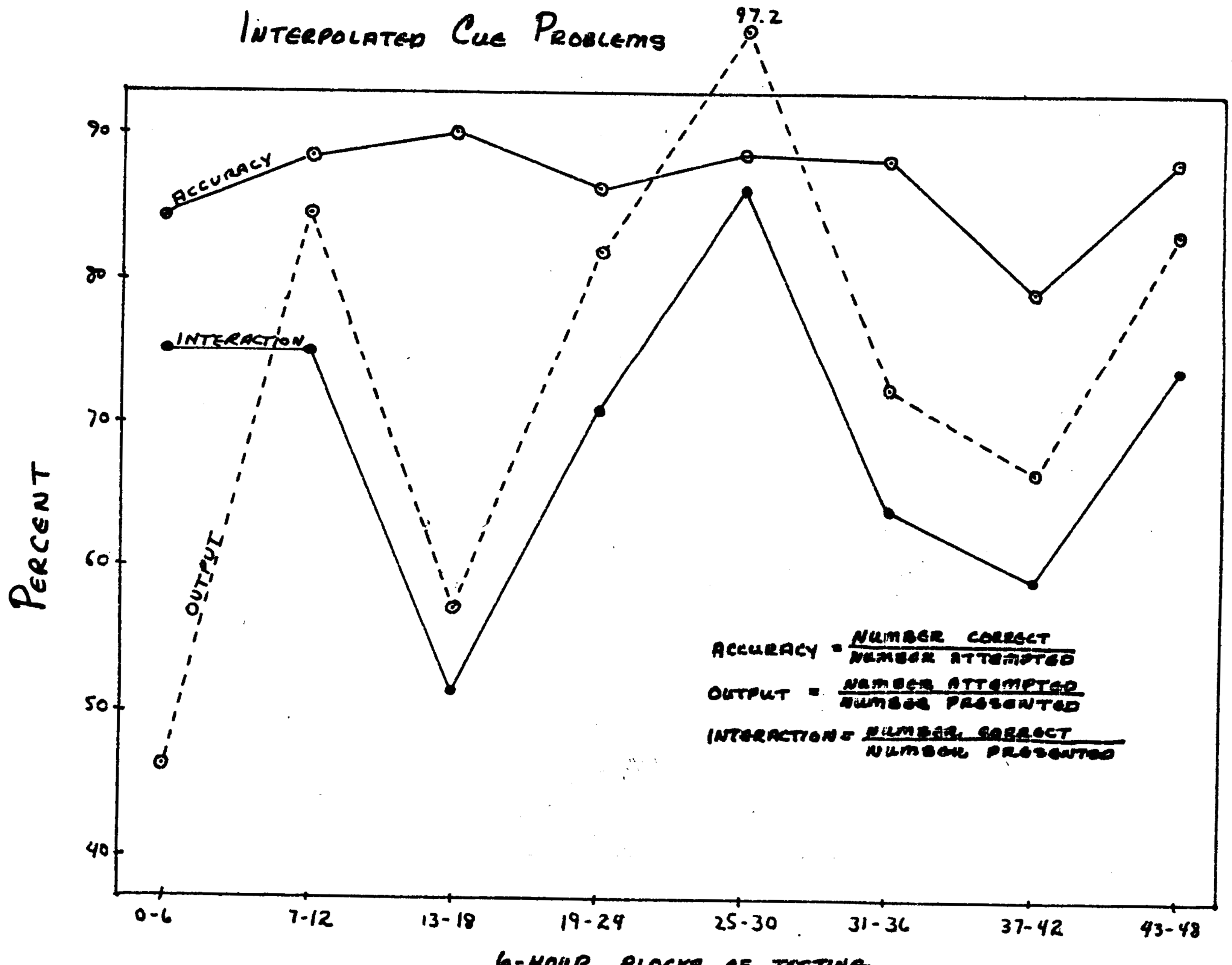


FIGURE 13. PERFORMANCE OF MA-5 ON INTERPOLATED CUE PROBLEMS OF ORBIT 108. NO SHOCK.

MARCH 31, 1964.

Reversal Problems.

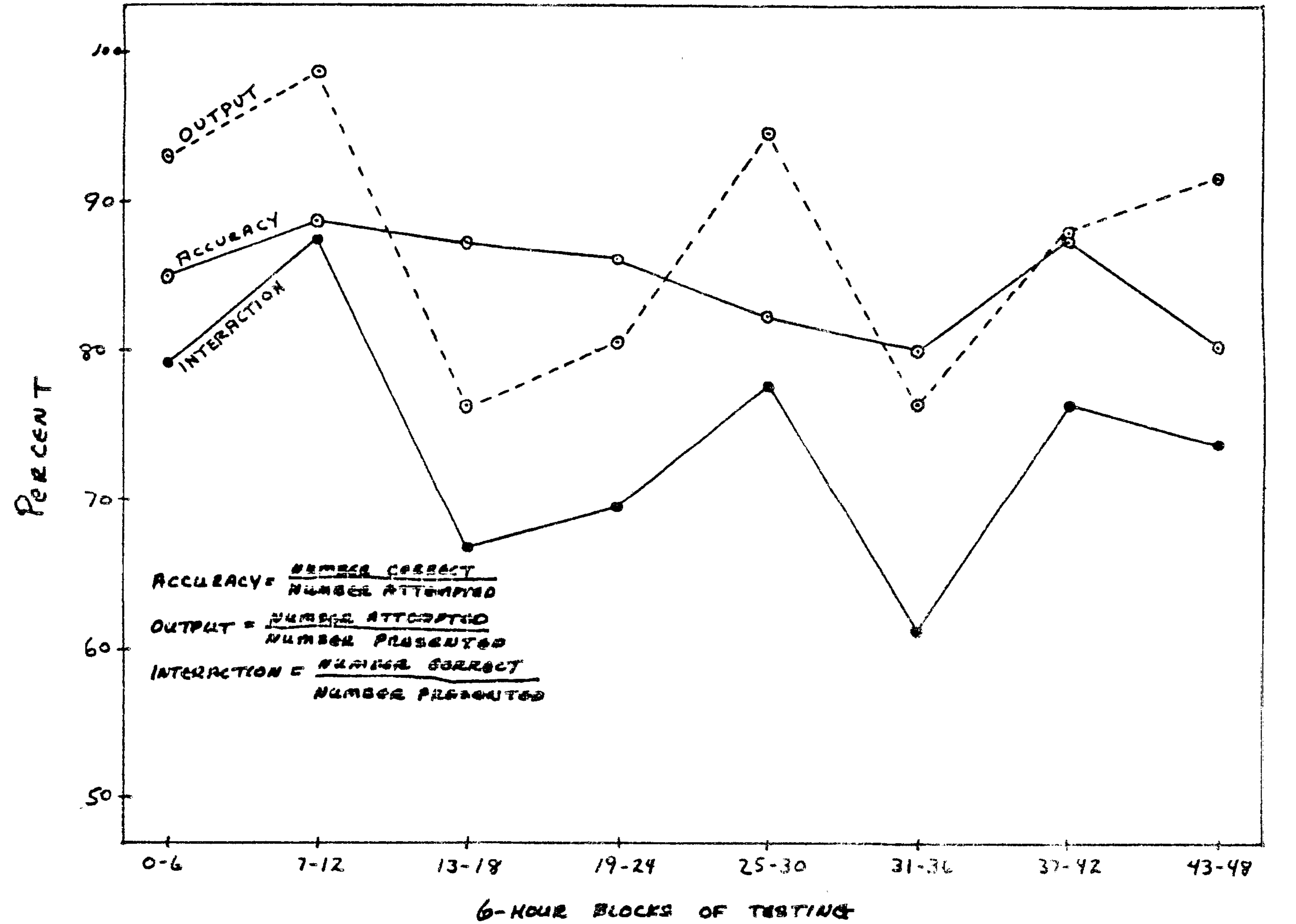


Figure 1A. Performance of RA-5 on reversal problems of Orbit 10B in which reversals were still between rather than within problem sessions. No shock.

March 31, 1964.

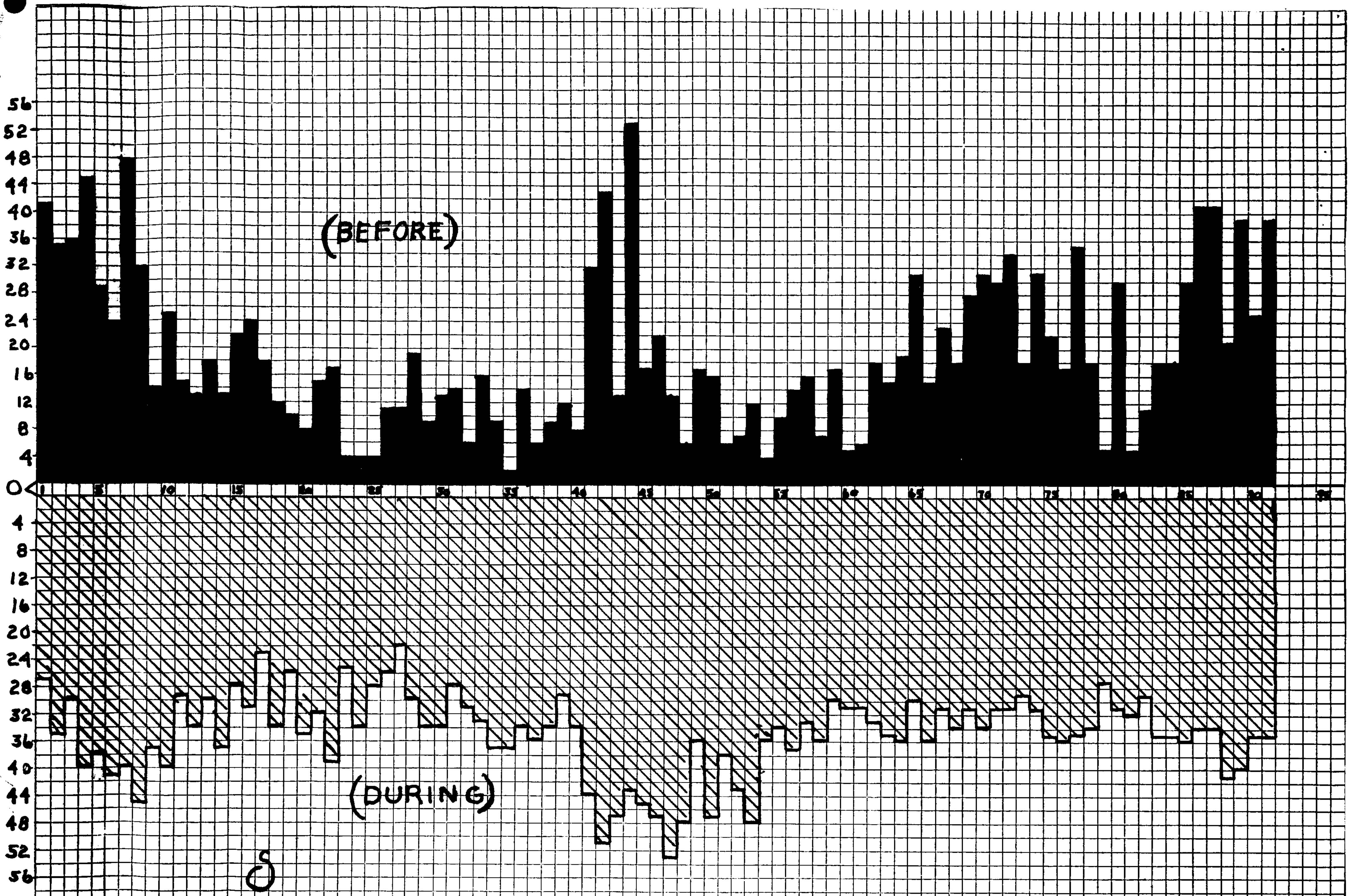


FIGURE 15

87-NA9-9-03

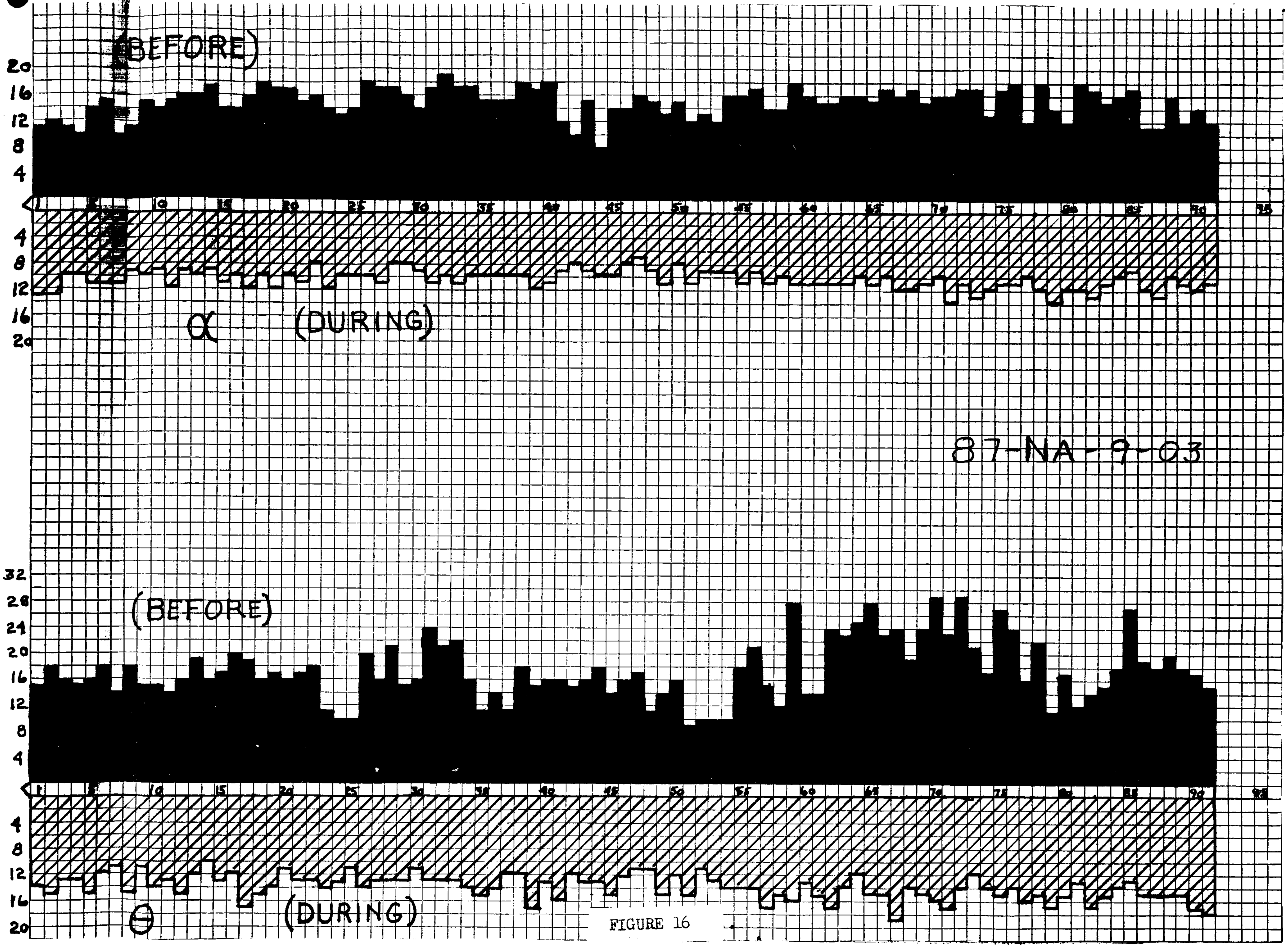


FIGURE 16

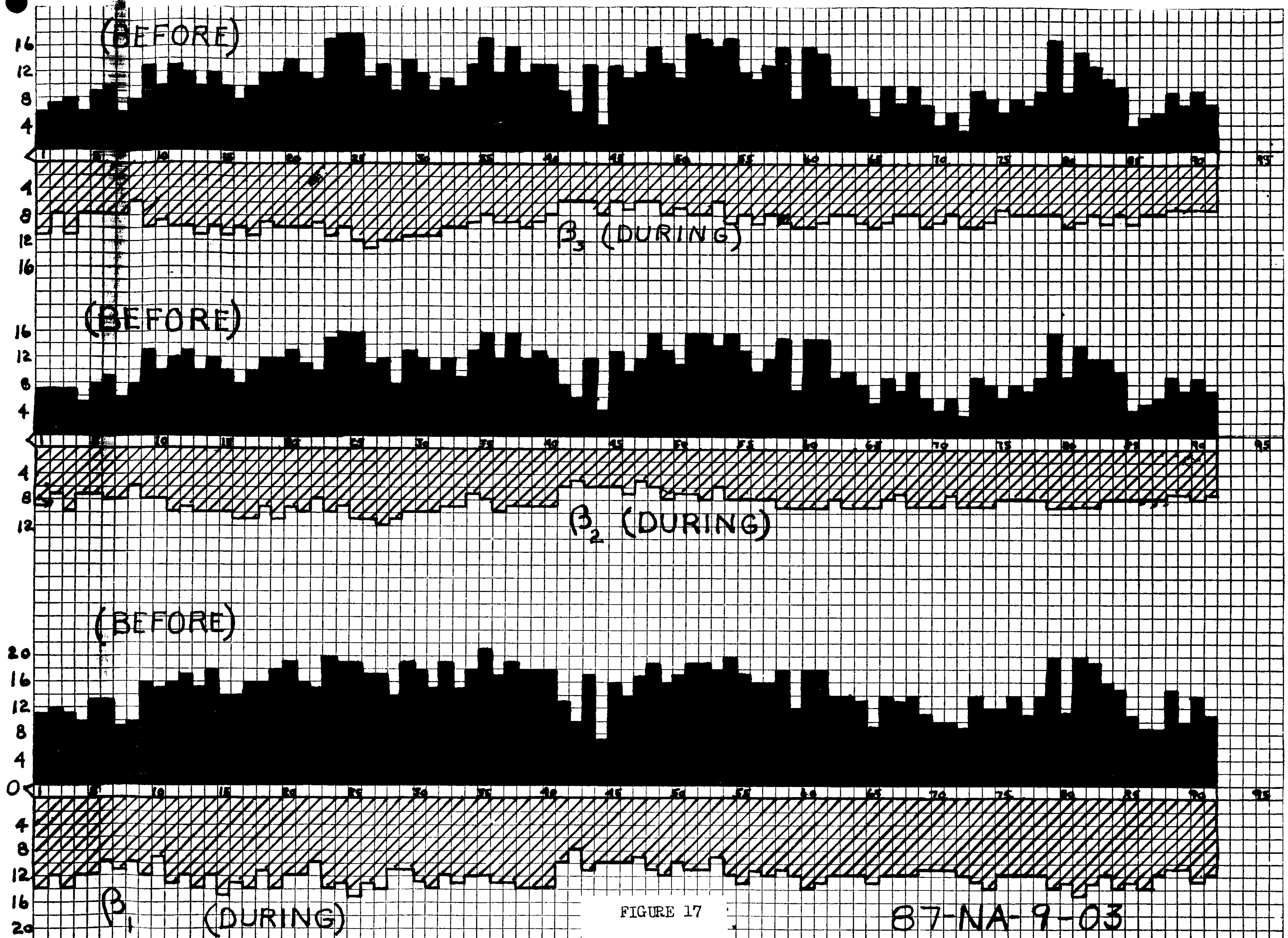


FIGURE 17

87-NA-9-03

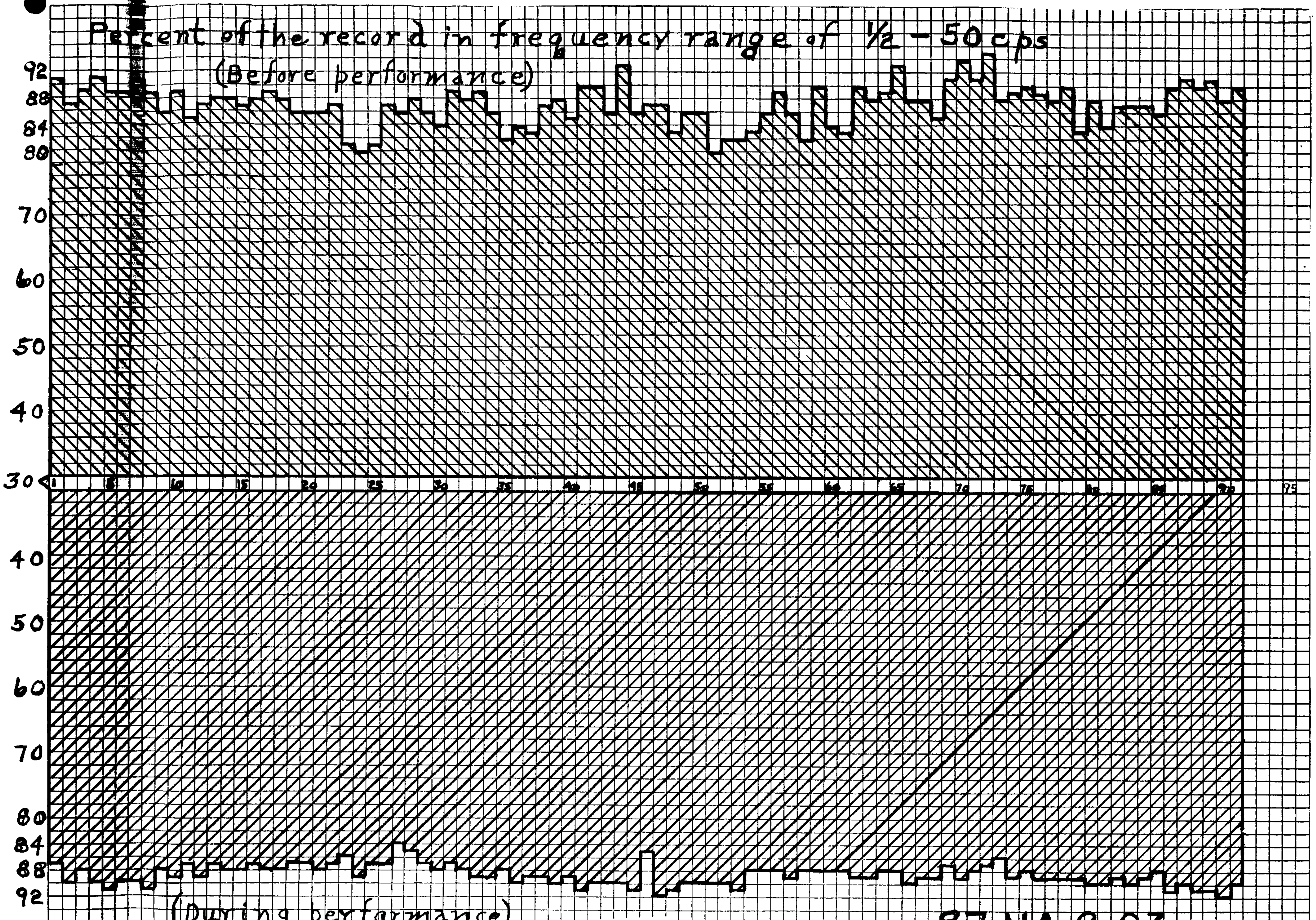
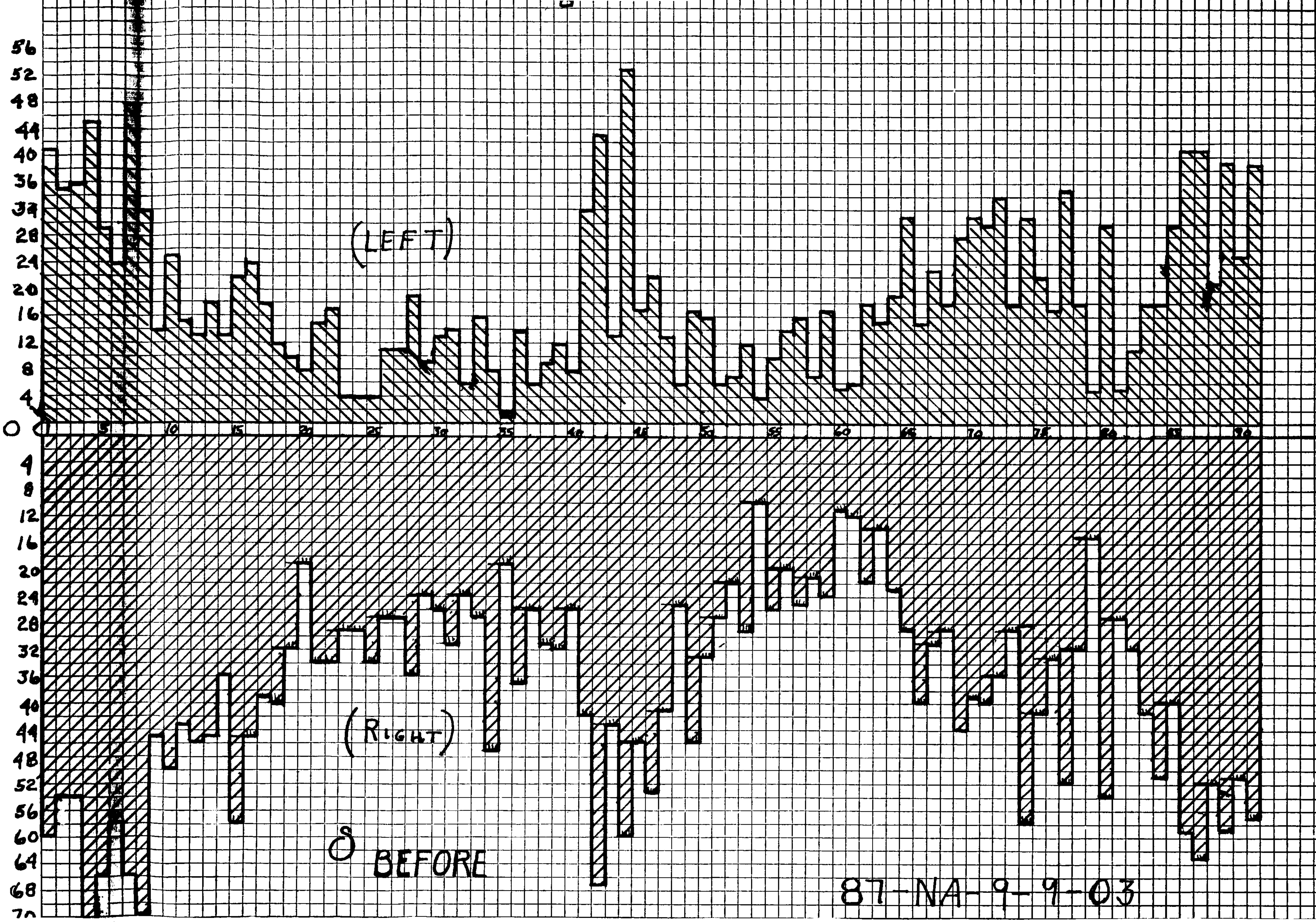

Percent of the record in frequency range of ½ - 50 cps
(Before performance)
(During performance)
92
88
84
80
70
60
50
40
30
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
87-NA-9-03

FIGURE 18

FIGURE 19



56
52
48
44
40
36
32
28
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36
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52
56
60
64
68
70
5
10
15
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25
30
35
40
45
50
55
60
65
70
75
80
85
90
(LEFT)
(RIGHT)
♂ BEFORE
87-NA-9-9-03

FIGURE 20

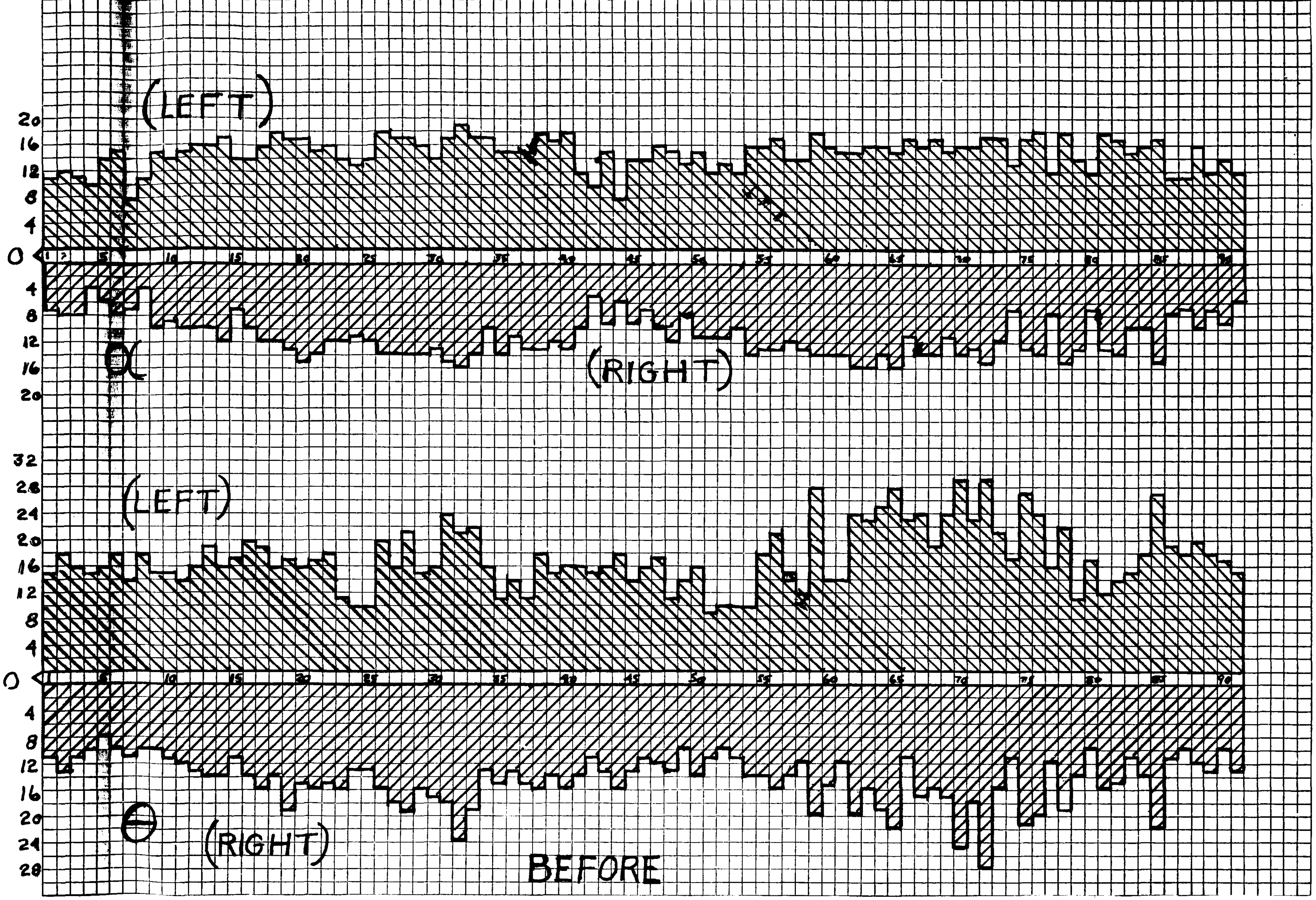
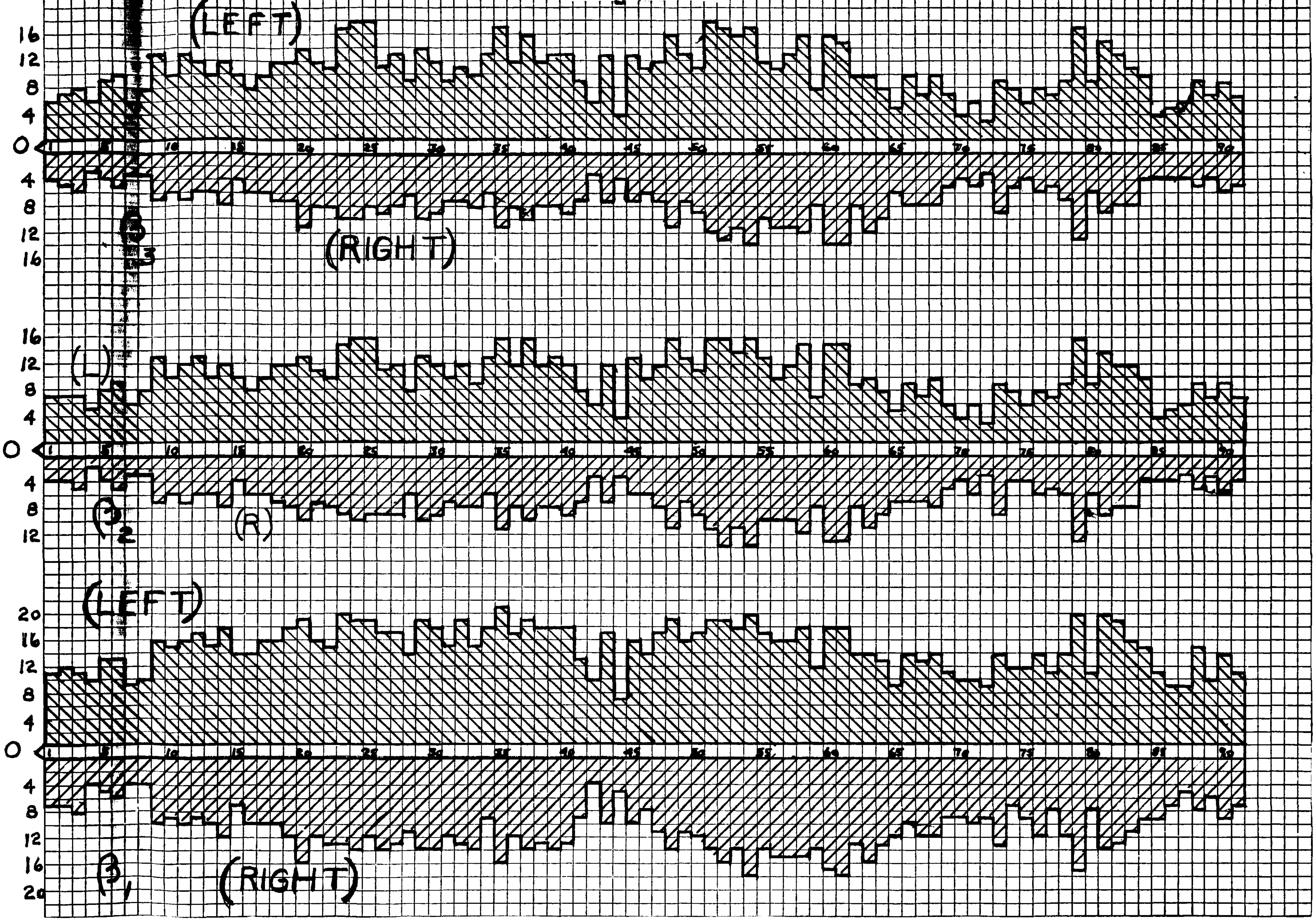
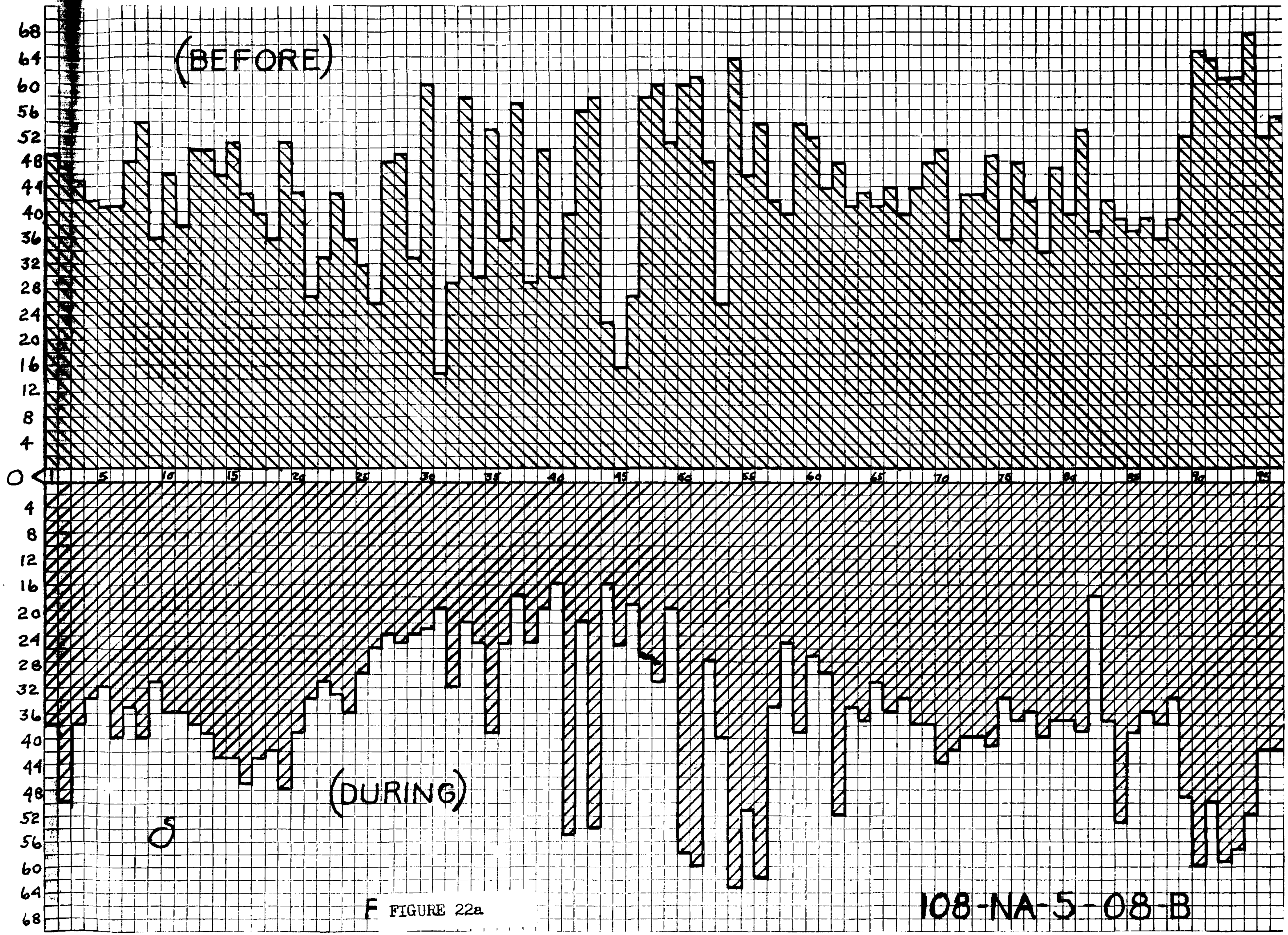


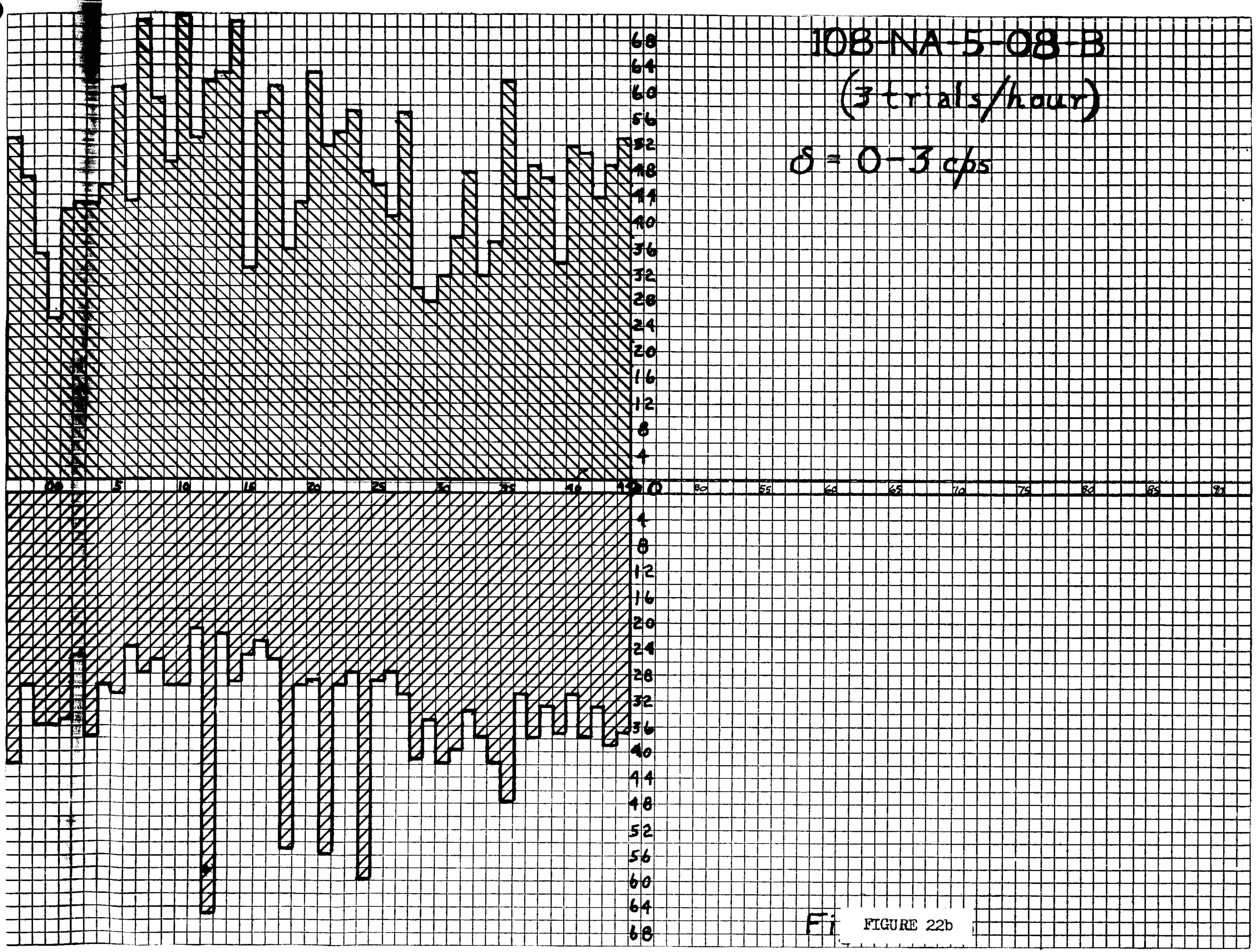
FIGURE 21





F FIGURE 22a

108-NA-5-08-B


108-NA-5-08-B
(3 trials/hour)
δ = 0-3 cps
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
00
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
FIGURE 22b

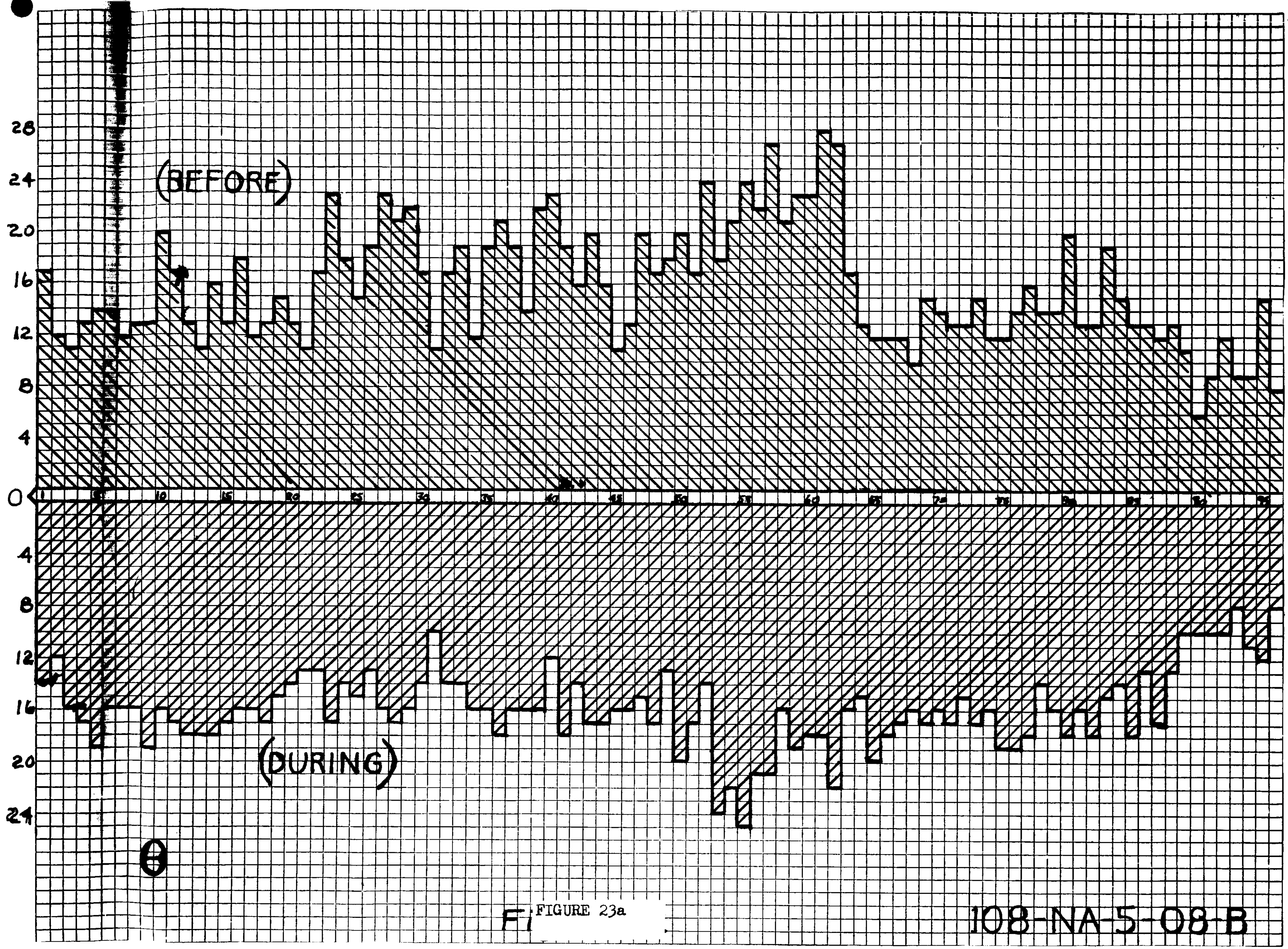


FIGURE 23a

108-NA-5-08-B

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(48 hour orbit with performance decrement)

Θ = 4-7 cps

FIGURE 23b

108-NA-5-08-B

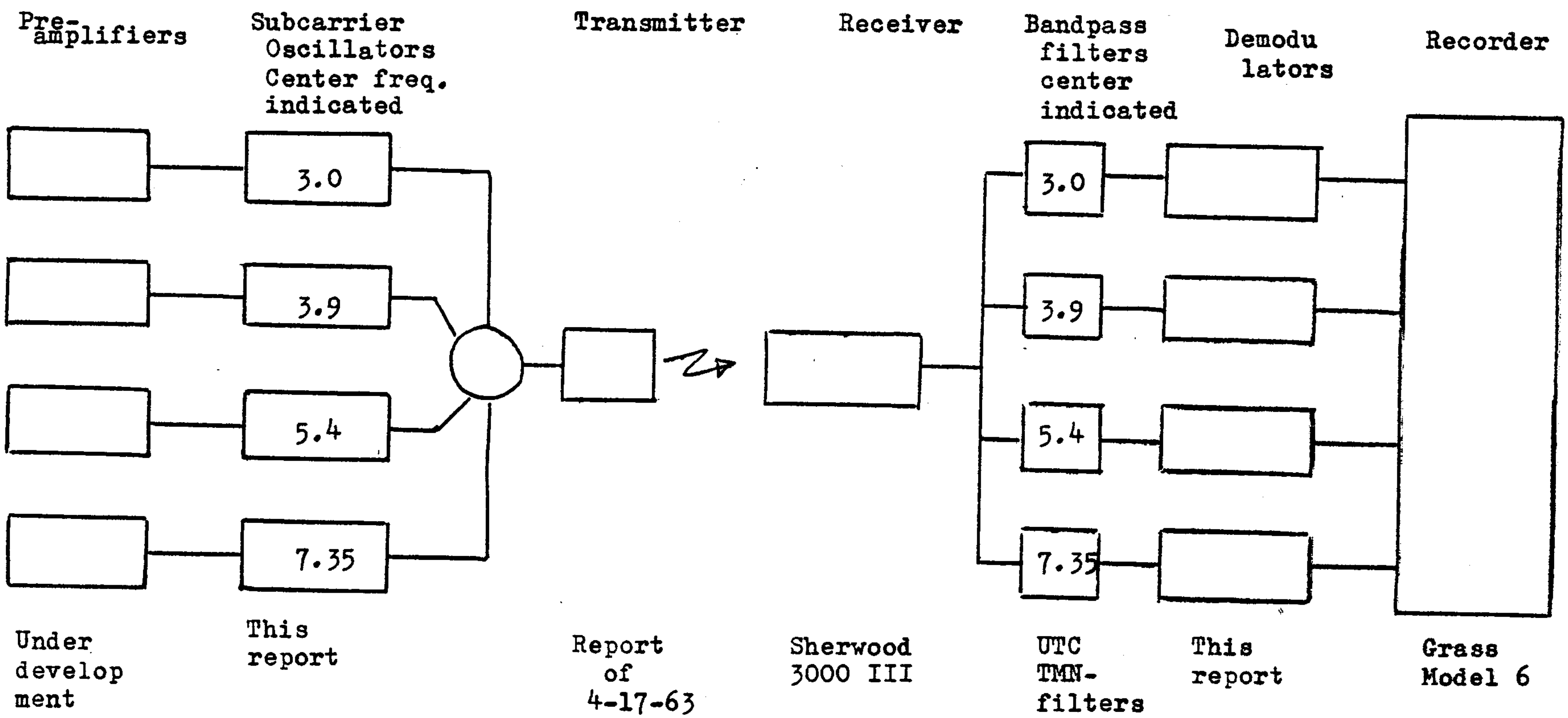

Fig. 24. Four Channel Frequency multiplexing FM-FM telemetry system.

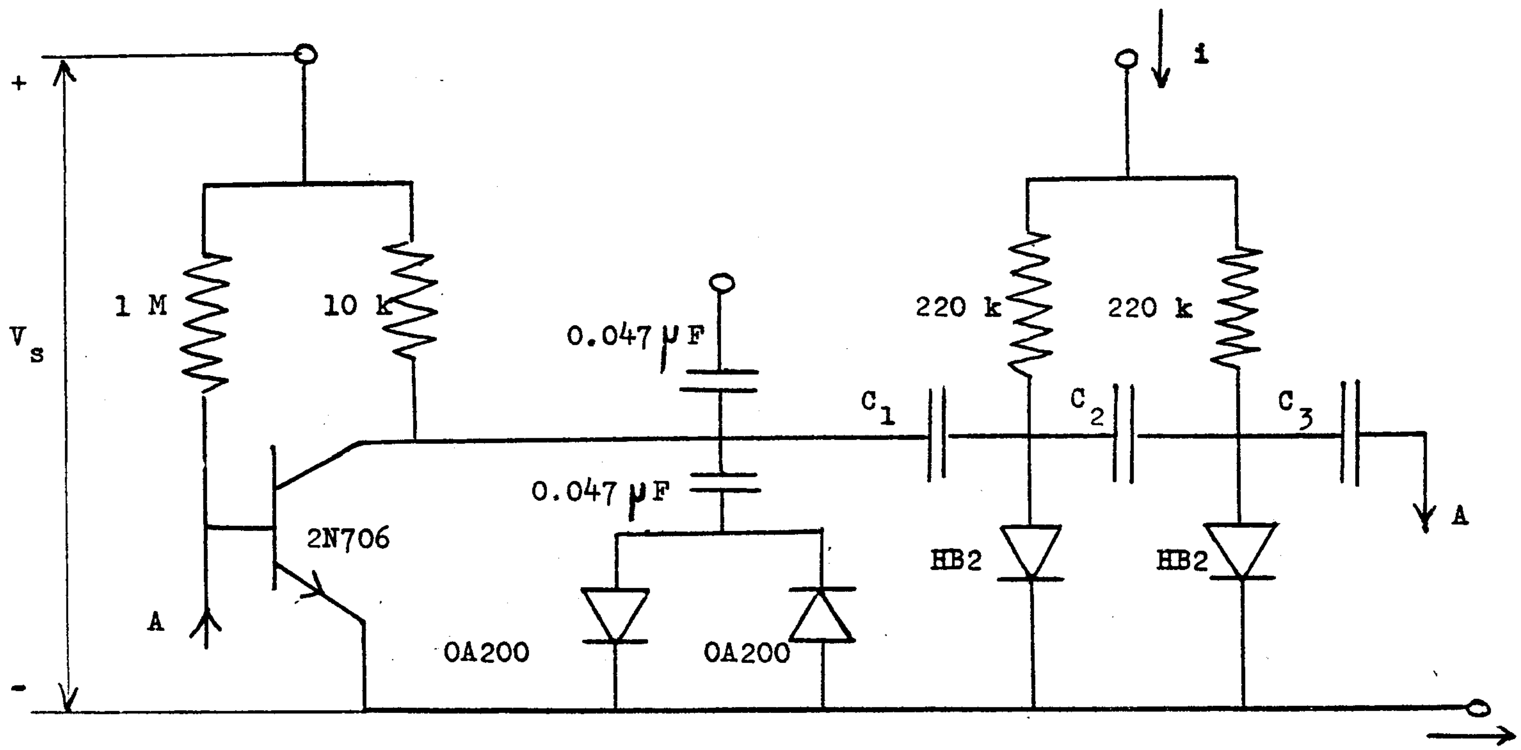

Fig.25 Sub-carrier oscillator circuit.

Fig. 26 Sub-carrier oscillator frequency versus control current.

(breadboard circuit)

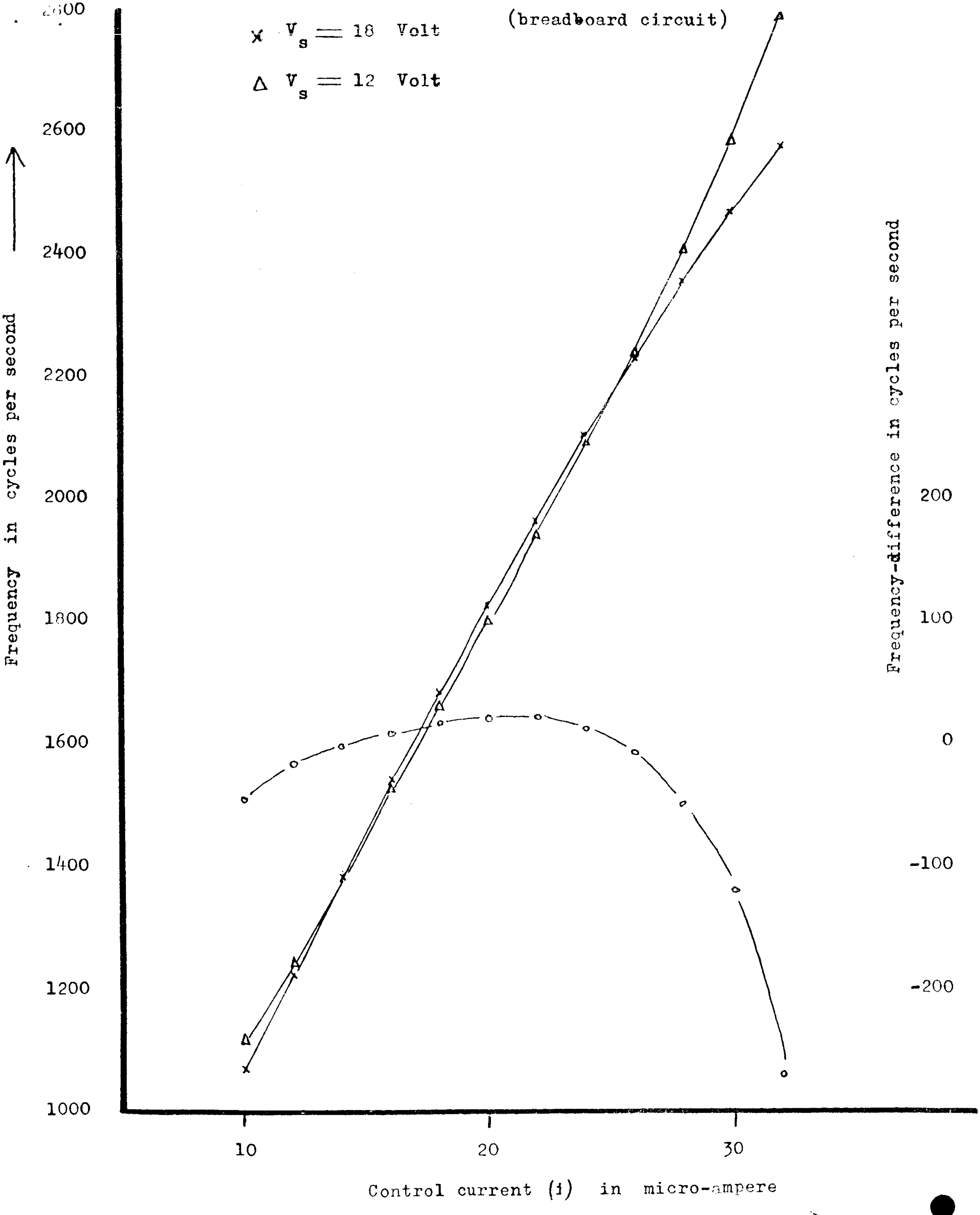

Fig. 27 Sub-carrier oscillator frequency versus control current and IRIG* bands.